Advanced Lighting Control System (ALCS) in an Office Building

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EXECUTIVE SUMMARY

This report summarizes an assessment project conducted to study the performance of an advanced lighting control system (ALCS) in a generic office setting. After relamping, reballasting, and adding wireless controls to the existing lighting fixtures, baseline measurements were taken. An initial energy savings of 26% resulted from the implementation of task tuning through the ALCS. A further energy savings of 44% resulted from the implementation of complete ALCS functionality, based on the results of the test at the Contra Costa County Office of Education ending in January 2013.

ANALYSIS OF PHASED APPROACH

To assess the energy savings potential of linear fluorescent lighting with an ALCS, the control strategies were implemented incrementally and monitored in the following phases:

1. Baseline, new linear fluorescent T8 lamps and dimming ballasts at full power
2. ALCS with task tuning only (approximately 70% powered) using a wireless control system from Enlighted
3. ALCS with task tuning and daylight harvesting using sensors from Enlighted
4. ALCS with task tuning and occupancy sensors using sensors from Enlighted
5. Fully functional ALCS (task tuning, daylight harvesting, and occupancy sensor control)

Energy was saved at each phase. Task tuning the light level for different spaces (Phase 2) not only provided a stable reduction in power for the entire floor, but also offered the most savings. Implementing daylight harvesting (Phase 3) provided minimal savings, while occupancy sensor control (Phase 4) provided significant savings.

If a more aggressive task tuning approach had been implemented (with each space individually tuned to user requirements or standard illuminance values), then the savings for task tuning would increase. The savings from daylighting and occupancy sensors might not vary by much from the levels measured in this study.

PRODUCT DISCUSSION

In this study, existing fluorescent fixtures were retrofitted with dimming ballasts and new lamps. ALCS provided a control platform that permitted fixtures to be individually tuned, switched, or dimmed.

APPLICABILITY

The high degree of configurability offered by this fixture-control pairing is attractive to customers, especially those who have an interest in maximizing both customized distributed environmental control and sustainable energy saving practices.

POTENTIAL BARRIERS

The simple payback period calculated in this study is generally longer than 12 years. The project economics at this stage in the technology development of ALCS are a barrier to market adoption for most commercial customers, particularly in a retrofit situation, where functioning lights and equipment may need to be replaced. By contrast, not all sites will require new lamps and ballasts if their fixtures already house compatible dimming ballasts, which will reduce the initial cost and provide a more favorable payback.

Moving forward, standards for implementation of lighting controls are vital to ensure energy savings. Standards should include those for establishing a baseline, commissioning the

product, and reporting the results. Standards and future policy decisions to promote market adoption should give users increased confidence in performance reliability.

VARIABILITY OF SAVINGS POTENTIAL

The project economic analysis presented in this report is calculated using information specific to this customer site. The project economics can vary significantly based on site-specific variables, such as lighting operating hours, installed lighting power density (W/ft²), ALCS installation cost, electricity cost, and others. Readers are advised to use information specific to your facility when evaluating project economics.

POTENTIAL BENEFITS BEYOND ENERGY SAVINGS

ALCS is recommended as a utility-approved energy savings measure for a variety of reasons besides yielding proven energy savings. An ALCS promotes increased flexibility in the configuration and tailoring of light levels based on space requirements and user preference. Additionally, dimming light sources through use of an ALCS can extend lamp and ballast life. An ALCS allows light sources to be controlled with precision.

INTRODUCTION

Wireless lighting controls are an emerging energy-efficient technology that can be coupled with advanced light sources (such as LED lighting) or can be used with state-of-the-shelf lighting systems, including newer generation T8 lamps paired with solid state ballasts.

PG&E seeks to broaden its incentive program for energy savings by testing advanced wireless control systems in a variety of settings and with a variety of sources.

For this project, PG&E teamed with EMCOR Energy Services to conduct a test on the third floor of the Contra Costa County Office of Education (CCCOE) at 77 Santa Barbara Road in Pleasant Hill, CA. The goal of the study was to evaluate the impact of an advanced lighting control system on a dimming fluorescent lighting system in a generic office setting.

PG&E made arrangements with CCCOE and Enlighted Inc., a manufacturer of wireless lighting controls, to implement a wireless control system. Enlighted worked with the installation firm Positive Energy to complete the initial upgrade in August 2012. Field measurements were conducted through January 2013, testing baseline and controlled operation conditions using a variety of lighting control settings.

The simple payback period associated with the implementation of fixture retrofit and controls for this study is about 13 years. The payback period reflects the project costs associated with relamping and ballasting the existing fixtures as well as the cost of the controls, which totaled about $27,000. The savings were calculated to be 12,763 kWh/yr based on normalization and extrapolation of the test data. The dollar value of the savings was calculated at $2,120/yr based on current PG&E electricity rates for a medium-sized office building.

BACKGROUND

The average energy savings of lighting controls, according to the best current estimates, are 24% for occupancy controls, 28% for daylighting controls, 31% for personal tuning, 36% for institutional tuning, and 38% for multiple approaches in commercial buildings.[1] Lighting is the largest single category of end-use energy consumption in the commercial sector. Lighting accounts for 38% of all electricity used within commercial buildings and contributes to about 20% to 30% of peak hour commercial loads.[2]

Lighting upgrades are adopted whenever cost effective efficiency improvements appear in the marketplace, as is well demonstrated through the rapid acceptance of T8 fluorescent lamp and electronic ballast upgrades over the last twenty years. This phenomenon is especially true in the commercial sector and in Class A office space particularly. Property managers and owners tend to be early adopters of technology, having resources and making investments to promote competitive sales and leasing. Visual comfort, a modern image, sustainability, user choice, and other intangibles might result from an advanced lighting control upgrade. Improved lighting with advanced lighting control systems could potentially reduce overhead operating cost (through energy and maintenance savings) as well as boost worker well-being and productivity. For these reasons, an office space provides an appropriate setting to test acceptance of advanced lighting control systems (ALCS).

Presently, linear fluorescent lighting illuminates the majority of commercial facilities. Linear fluorescent sources comprise 80% of installed commercial lighting, compact fluorescent sources comprise 10%, and incandescent, halogen, high intensity discharge, or other sources comprise 10%.[3]

[1] Williams, Alison, et al. (September 2011), *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL Paper LBNL-5095E. http://escholarship.org/uc/item/7kc8n19w The meta-analysis included 88 papers and case studies published from 1982 to 2011.

[2] Rosenberg, Mitchell (August 2012), *Moving Targets and Moving Markets in Commercial Lighting*. Washington, DC: American Council for an Energy-Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings. http://www.aceee.org/files/proceedings/2012/data/papers/0193-000084.pdf

[3] Ashe, Mary, et al. (January 2012), *2010 U. S. Lighting Market Characterization*. Washington, DC: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2010-lmc-final-jan-2012.pdf

EMERGING TECHNOLOGY/PRODUCT

The benefit of easy digital control enables an advanced, wireless control system. Lighting controls have advanced significantly over time—from wired rheostat dimmers to auto-transistors, switching relays, and now to wireless controls. Each advance has reduced energy consumption and permitted added control capabilities. This project considers a few market options which can be incorporated into a wireless control network: daylight sensors and occupancy sensors.

Daylight sensors have been on the market for over ten years but still are not prevalent. They respond to artificially and naturally overlit conditions, dimming either independently or by means of an energy management system or ALCS. Unlike occupancy sensors, daylight harvesting can produce significant energy savings during peak periods when electricity rates are highest, which can improve the project economics.

Ultrasonic and infrared occupancy sensors have been available for over twenty years. Consequently, their commercial presence is greater and more is known about their capabilities. Like daylight sensors, occupancy sensors can function independently or with an energy management system or ALCS. Savings depend on the occupancy rate and duration, sensor type, layout, time setting, and commissioning.[4]

A wireless ALCS that responds to the sensors has significant benefits compared to the wired alternative:

- The wireless design reduces material and installation costs.
- The wireless design facilitates access and servicing.
- The wireless network scales easily and can be expanded cost effectively.
- The wireless network simplifies and enables easier tuning of fixtures and other equipment.
- The wireless design permits customization per space requirements.

[4] Brambley, M.R., et al. (April 2005), *Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways*. Washington, DC: U.S. Department of Energy. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/pnnl-15149_market_assessment.pdf

ASSESSMENT OBJECTIVES

The main objective of this field assessment is to evaluate the energy savings potential of an ALCS in an office environment. Determining proven designs and reliable solutions will enable PG&E to broaden its incentive programs for commercial customers to potentially upgrade or expand their lighting controls systems.

The product evaluated in this project is still relatively new and not widely adopted. Wireless networks in lighting designs are used in practice. However, the performance of an ALCS in real world installations has not been broadly studied.

To assess the energy savings potential of an ALCS, control strategies are implemented incrementally and maintained for a fixed period of time before additional strategies are enabled. Based on the data collected from each period, the energy consumption can be determined and compared to the energy consumption from the other periods to determine the savings attributable to each set of control strategies.

The baseline case for this project consists of the incumbent fluorescent fixtures retrofitted with new T8 fluorescent lamps and dimming electronic ballasts operating at full power with manual on/off controls. Advanced lighting controls are then enabled, and control strategies are implemented incrementally and monitored.

The field assessment covers five periods, or phases, as follows:

- Phase 1 (baseline case): monitoring period of fixtures at full power, on/off-controlled via wall switches.
- Phase 2 (ALCS task tuning only): monitoring period of fixtures dimmed to approximately 70% power, on/off-controlled fixtures via wall switches.
- Phase 3 (ALCS task tuning and daylight harvesting): monitoring period of task-tuned fixtures with daylight sensors enabled. The daylight sensors dim the light fixtures as more natural light enters the space and brighten the light fixtures as the available sunlight lessens.
- Phase 4 (ALCS task tuning and occupancy sensors): monitoring period of task-tuned lights with occupancy sensors enabled. Occupancy sensors dim the light to 20% if the space is unoccupied for several minutes. If the area remains vacant for another several minutes, the lights shut off.
- Phase 5 (fully functional ALCS: tasked tuning, daylight harvesting, and occupancy sensors): monitoring period of task-tuned fixtures with daylight and occupancy sensors. Daylight sensors function as described in Phase 3. Occupancy sensors function as described in Phase 4.

Data loggers were installed at the lighting panel and at five targeted work areas on the office floor. Variables were collected every five minutes. The analysis focused on power and illuminance measurements, and also reviewed power factor. The goal was to determine the energy savings and lighting performance impacts for each phase as the lighting system changed and control strategies were implemented.

For the dates and other details of the actual phases, see Test Plan.

TECHNOLOGY/PRODUCT EVALUATION

Linear fluorescent light fixtures have been available for years and are a proven, reliable technology, but the energy saving potential of pairing these lights with an ALCS is not well understood. For this project, linear fluorescent fixtures with two 32 watt T8 lamps and electronic dimming ballasts were tested with wireless lighting controls. CCCOE utilized a local company, Enlighted, to facilitate procurement of the new lamps, ballasts, and controls and complete the retrofit of the existing fixtures. Enlighted worked with an installer, Positive Energy, to ensure that the sensors and hardware were properly installed and configured.

A variety of sensor and control technologies are available in the market. Consequently, PG&E, EMCOR, and CCCOE met with Enlighted to consider the available control products. For the project, Enlighted provided daylight and occupancy sensors, dimming controls, and wireless controls.

The products included in this study had the following specifications:

- Sylvania Octron Ecologic 32 W T8 Lamps (F032/741/ECO) with a rated color temperature of 4,100 K.
- GE Ultra Start T8 ballasts with 0-10 volt dimming (GE232MVPSN-V03).
- Enlighted provided their gateways and Enlighted Energy Manger (EEM), which is the user interface to the Enlighted Intelligent Lighting Control System. The gateways connect the Enlighted Smart Sensors and EEM via a wireless network.
- Enlighted supplied the Enlighted Smart Sensor (SU-2-00), which senses occupancy, temperature, and ambient light. These Smart Sensors also perform the wireless communication with the gateways and EEM. The Enlighted Smart Sensor has a major motion sensing radius of approximately 1.25 times the mounted height, giving it approximately a 10 ft radius for major motion and a 6.5 ft radius for minor motion when mounted on an 8 ft ceiling, or 11.25 ft and 7.3 ft when mounted on a 9 ft ceiling, which is the approximate ceiling height at CCCOE.
- Enlighted provided the control units (CU-2-1r), which are installed in line with the dimming ballast and hard wired to the Smart Sensor. The control units provide the dimming and on/off control of the fixtures. Additionally, each control unit is equipped with power and energy monitoring capabilities.

PRODUCT CONFIGURATION

The ALCS was tested in a real world office installation, an appropriate choice because lighting use in an office can be found only in a real world situation. Implementing the study using occupants working and testing the lights is essential to determining the energy savings. A lab test could discern the "best" solution under strict conditions, but would not account for the variability that occurs in an office. Simulations generally overestimate the savings achievable in the field, especially for daylighting.[5]

As a practical matter, varying illuminance levels can be measured at desk (or work) level along with the impact of a new ALCS. Office spaces tend to be wired electrically in a modular, uniform way such that energy consumption can be separated and aggregated with relative ease.

The CCCOE building at 77 Santa Barbara Road, Pleasant Hill, CA was the host site for the field assessment. The project scope included the south portion of the third floor. The physical requirements were simple: office space utilized by end-users who would have regular exposure to the environment, both before and after the retrofit. The project required access to these workers for surveys, accommodations for equipment on site, the installation and configuration of equipment, building access even in off-hours, commitment to support the project for its duration, and a publication of findings.

Prior to this project the office space was lit with 2 lamp T8 fluorescent fixtures with electronic ballasts. These fixtures were relamped with 32 W T8 fluorescent lamps and retrofitted with dimming ballasts, wireless controls, and dual technology sensors (occupancy and daylight). The retrofitted fixtures were monitored at full power with all wireless control functionality disabled for a period before implementing individual wireless control functions. For that monitoring period (Phase 1), the controls other than simple on/off manual controls were disabled.

EMCOR coordinated with Enlighted to complete the installation of all equipment. Once the baseline monitoring was completed, Enlighted set up their wireless system, task tuned the lights, and capped "full" power at 80% of the lamp ballast capacity. Enlighted implemented and modified the control strategies and assigned addresses to the fixtures, necessitated by the wireless controls.

Manual user control was enabled for all phases. The first two phases lacked any dimming or automatic shutoff, which was provided in Phase 3 by means of daylight control and in the Phase 4 with occupancy sensors. The daylight sensors dim based on the natural light entering a zone; the occupancy sensors are standard motion sensors that first dim and then turn off the lights when no motion is sensed for several consecutive minutes. The schematic layout is provided in the monitoring plan in Appendix C.

[5] Williams, Alison, et al. (September 2011), *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL Paper LBNL-5095E. http://escholarship.org/uc/item/7kc8n19w The authors conclude that energy policy and savings estimates should not be based on simulations alone but should include field measurement.

TECHNICAL APPROACH/TEST METHODOLOGY

FIELD TESTING OF TECHNOLOGY

The test site is the CCCOE building in Pleasant Hill, CA. Data was collected for five distinct spaces on the third floor south. The spaces are one private office, two open offices with south facing windows (cubicles), one interior open office (cubicle), and one non-daylight area. Data was also collected for the entire third floor south (referred to as the lighting panel H3S).

The private office (A1) is on the north side towards the east end of the floor. The area has three windows, all on the north wall, and four light fixtures.

Two of the open office areas (A2 and A5) are on the south side of the floor, and each has two windows on the south wall. There are 22 light fixtures in the two open office areas.

One interior, non-daylight zone (A3) is located near the northeast corner of the floor. The area has four fixtures that provide light to a single cubicle and the entryways to one small conference room and two private offices. The area is the most isolated from natural daylight. One light fixture is directly over the cubicle, and the other three fixtures serve the common areas between the cubicle and the entryways.

The other interior open office area (A4) is located near the center of the floor and has no direct windows. There are 16 fixtures serving this open office area. Some daylight reaches the space from the adjacent windows on the north and south exterior walls.

Panel H3S refers to the entire third floor south project area. Data was collected for the entire project area, and the data included fixtures not monitored in the areas described above. In other words, the sum of the fixtures in area A1–A5 is less than the total number of fixtures on the floor (panel H3S).

Daylight harvesting was implemented in Phase 3 and again in Phase 5, but the results were affected by the time of year (winter months), occupant control of window blinds, and the fact that the majority of the space was not being directly impacted by daylight. This control strategy had a minimal impact on the overall project savings for this facility.

For a sense of the area most affected by daylighting, see Figure 1 with photographs of the open office by the window. Other photographs of the spaces are in Appendix B.

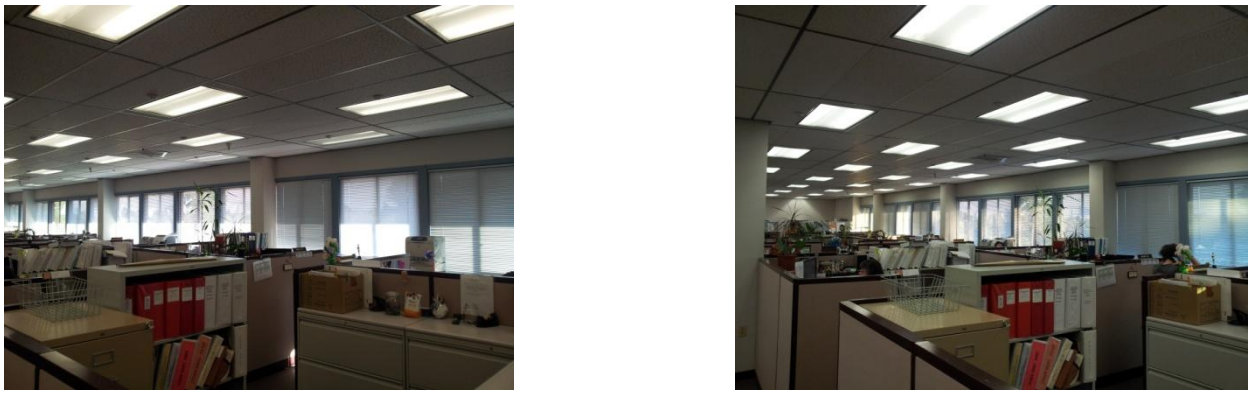
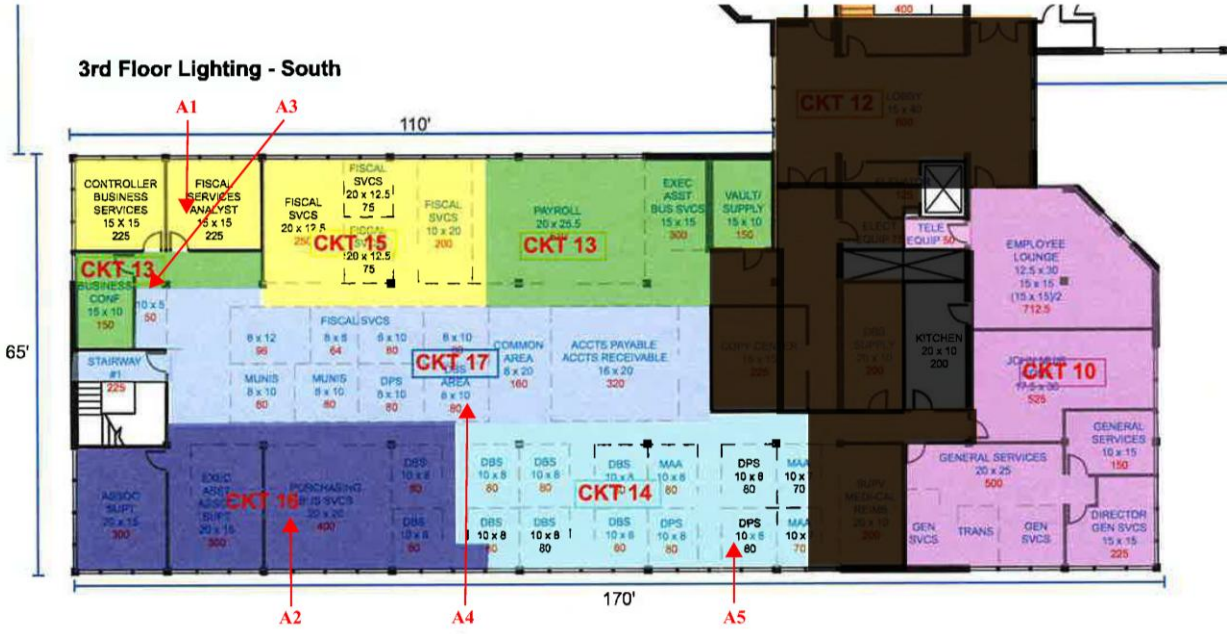


FIGURE 1. DAYLIGHTING CONTROL: DIMMED LIGHTS NEAR WINDOWS (LEFT) AND UNDIMMED LIGHTS 1.25 HOURS LATER

The table and map below summarize the monitored spaces.

TABLE 1. MONITORED SPACES

SPACE	LOCATION	DESCRIPTION
A1	North side	3 windows and 4 fixtures.
A2	South side	2 windows and 6 fixtures.
A3	Interior	No direct windows and 4 fixtures.
A4	Interior	No direct windows and 16 fixtures.
A5	South side	2 windows and 17 fixtures.
Panel H3S	Entire project area	6 circuits, 162 fixtures. Panel H3S is in an electrical closet.



Project area excluded grayed out area (CKT 12)

Arrows A1 - A5 indicate approximate location of illuminance sensors

FIGURE 2. MAP OF MONITORED SPACES

TEST PLAN

This project met the International Performance Measurement and Verification Protocol (IPMVP) guidelines for Option A, "Partially Measured Retrofit Isolated." The protocol is appropriate because the project focuses only on lighting and the directly related loads (which can be measured at the light and power sources and illuminated surfaces). Indirect changes, such as an increased or decreased space temperature, are not considered in this project.

The protocol requires short-term or continuous post-retrofit measurements, and the project complies. Measurements are taken frequently—every five minutes. Each phase with a specific set of functional control strategies is held for three weeks before the next implementation. Three weeks is a sufficient period to recognize reliable patterns and account for infrequent changes in the office. This period length is standard for each phase.

EMCOR visited the test site weekly during the monitoring periods to collect the data and check the equipment. EMCOR was aware of all the fixtures, equipment, and programmed control functionality. Routinely, EMCOR reported to PG&E and contacted the subcontractors to address any issues.

The monitoring plan with the map of the sensors and control submitted to PG&E for the project is in Appendix C.

The project evaluates the retrofit linear fluorescent fixtures with dimming ballasts at full power for the baseline case (Phase 1) and compares them with the other phases: task-tuned fixtures in Phase 2, task-tuned plus daylight harvesting in Phase 3, task-tuned plus occupancy sensor control in Phase 4, and finally full ALCS functionality enabled in Phase 5. The only manual controls for the lights throughout the entire project were to turn them on and off via the wall switch.

Electrical demand (wattage), illuminance (footcandles), power factor (percentage), and other data points were collected throughout the testing period, which was August 21, 2012, through January 23, 2013. Power, illuminance, and power factor were collected for individual spaces and circuit level at the panel H3S. Spot measurements of color temperature and illuminance were taken weekly during the data downloads.

EMCOR worked with the CCCOE to perform the installation of the data loggers and illuminance sensors in the workspace. Each monitored space is associated with its own power data logger.

Downloading of measurements typically occurred seven days, fourteen days, and twenty-one days after the start of each phase. There were various gaps between monitoring periods for several of the phases, as described below. The data captured during these gaps was considered irrelevant and was excluded from this study.

The phases are described below.

- Phase 1: (8/21/12 to 9/10/12) This is referred to as the baseline case. The T8 fluorescents were monitored for three weeks at full power, no dimming.
- Phase 2: (9/24/12 to 10/15/12) Once the Phase 1 monitoring period was complete, the fixtures were task tuned to approximately 80% of full power. Data was recorded at the same interval. The 14 day period between this monitoring phase and Phase 1 was due to Enlighted's two-stage approach to task tuning the fixtures. This two stage approach tunes down, or dims, the fixtures in two steps with an initial 10% to 15% reduction in fixture power draw followed by a second round of another 10% to 15% of reduction in fixture power draw.

- Phase 3: (10/16/12 to 11/6/12) The fixtures remained task-tuned and the daylight harvesting strategy was implemented, via the wireless controls, to all fixtures. Data was recorded at the same interval. A fixture near the A5 area had a lamp fail on 11/6/12; lamps were replaced the following day. The lamp failure affected only the panel H3S data because it was not one of the fixtures in the five selected spaces.
- Phase 4: (11/20/12 to 12/10/12) The daylight harvesting strategy was disabled, fixtures remained task-tuned, and the occupancy sensor control strategy was implemented. Data was recorded at the same interval. The 14 days between the end of Phase 3 and beginning of Phase 4 monitoring periods is attributed to an occupancy sensor programming issue that resulted in delaying the official start of this monitoring period.
- Phase 5: (1/2/13 to 1/23/13) Fixtures retained the features of Phase 4 and reincorporated the daylight harvesting strategy. This phase represented full implementation of the ALCS. Data was recorded at the same interval. The 31 day gap between the end of the Phase 4 monitoring period and the start of Phase 5 avoided the many atypical days that the CCCOE experiences during December (holidays, half days, and winter break).

INSTRUMENTATION PLAN

The following instrumentation tools were used to measure and collect data:

- The Summit Technology Current Probe (HA100) measures from 0.1 to 100 amps RMS AC current with an accuracy of ±2%.
- The Summit Technology PowerSight Power Logger (PS2500) measures the power and power factor with an accuracy of 1% plus the accuracy of the current probe. The THD measurements have an accuracy of 1%. The logger resolution is 1 second to 99 minutes.
- The T&D illuminance logger (TR-74 UI) has an accuracy of 5% for the 10 to 100,000 lux range. The tool refreshes every two seconds for the 5 minute interval and has a resolution of 0.01 lux.
- The Konica Minolta CL-200A Chroma Meter measured the color temperature during the weekly data collections. Its range is from 0.1 to 99,990 lux, and its accuracy is ±2% ±1 digit of the displayed value.

The monitoring plan is in Appendix C, including further information about the instruments.

COMMISSIONING PLAN

Enlighted's design incorporates an integrated occupancy, ambient light, and temperature sensor at each fixture. This approach simplifies the design phase and maximizes occupancy-based energy savings because each fixture is controlled individually. Prior to implementing the system, Enlighted staff meet with the facility's management to discuss fixture tuning strategies, any specific lighting requirements for space types and employees, building operating hours, and occupancy patterns. The building's lighting plan is then uploaded into the Enlighted Energy Manager program, and the fixtures are mapped for control and tuning.

Enlighted's traditional commissioning approach is spread over several phases in an effort to maximize the energy savings and to avoid surprising any of the space occupants with drastic changes to the lighting. Enlighted reports that typical commissioning phases are as follows:

- Task tune all fixtures by dimming them to reduce their power draw by 10% to 15% (85% to 90% power).
- Approximately one week later, implement a second round of task tuning by dimming the fixtures further for an additional 10% to 15% power draw reduction (now 20% to 30% total at 70% to 80% power).
- Two to three days later, add occupancy and ambient light sensing control to the fixtures using conservative timeouts so the lights take longer to dim and even longer to go to off.
- Continue to tune the fixtures by further dimming, if complaints are not widespread, and tighten up the dimming and fixture off timeouts.

Enlighted uses occupant feedback to determine when the system is optimally tuned for the particular space type and occupants. In general, the occupant feedback that Enlighted received for the CCCOE project was positive.

CCCOE occupants were satisfied with the light levels and with saving energy as a group. Occupants were also pleased that the fixtures would first dim and not just turn off. However, a few individuals were uncomfortable with the light levels after the second round of task tuning and wanted their lights to be brighter. These specific areas were adjusted back to the original task-tuned light level, or approximately a 15% reduction in power draw.

RESULTS

At the end of the monitoring period, all collected data was compiled to create a dataset of date, time, power, power factor, and illuminance for each space and the six lighting circuits monitored at the panel. The data was organized by space and phase.

After reviewing the data it was determined that all phases except Phase 2 (task tuning) had been effected by anomalies such has holidays or atypical weekend work. However, the anomalies typically occurred during only one week of each three week monitoring period. The anomalies were normalized by averaging the two remaining similar weeks when no anomaly occurred.

The following table indicates the cost and savings associated with each phase of the project.

TABLE 2. ENERGY SAVINGS (NORMALIZED) AND COSTS

PERIOD AND SAVINGS	PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5
Three Weeks of Energy Consumption (kWh)	1,808.7	1,334.8	1,309.6	1,028.1	1,018.8
Annual Energy Consumption (kWh)	29,177.6	21,545.7	21,148.5	16,513.5	16,414.4
Decrease in Annual Energy Consumption Compared to the Prior Phase (kWh and %)		7,631.9 26.2%	397.2 1.8%	4,635.0 21.9%	99.1 0.6%
Decrease in Annual Energy Consumption Compared to Phase 1 Baseline (kWh and %)		7,631.9 26.2%	8,029.1 27.5%	12,664.1 43.4%	12,763.2 43.7%
Cumulative Cost	$10,652	$26,662	$26,782	$26,902	$27,022

Table From Appendix File: Annual Normalization w_savings&payback (Electrical Demand).xls

The simple payback period for Phase 5 is 12.6 years.

The baseline lighting power density (LPD) for this project was calculated to be 0.99 watts per square foot, determined by the ratio of the maximum baseline power draw to the size of the project area. Similarly, the "task tuned" LPD was calculated at 0.73 W/ft² based on the maximum "task tuned" power draw.

DATA ANALYSIS

POWER

The electrical demand over a three week period for each phase appears in Figure 3. As expected, the electrical demand decreases as new control functions are implemented, resulting in less energy consumed over time. Figure 3 includes all anomalies captured during the project monitoring. By contrast, Figure 4 represents a typical week, free of anomalies, and is representative of the normalized data. While both figures show that the most significant reduction in electrical demand is attributed to task tuning the fixtures, the energy savings calculations also show that implementation of occupancy sensor control (Phase 4) contributes significantly to overall energy savings.

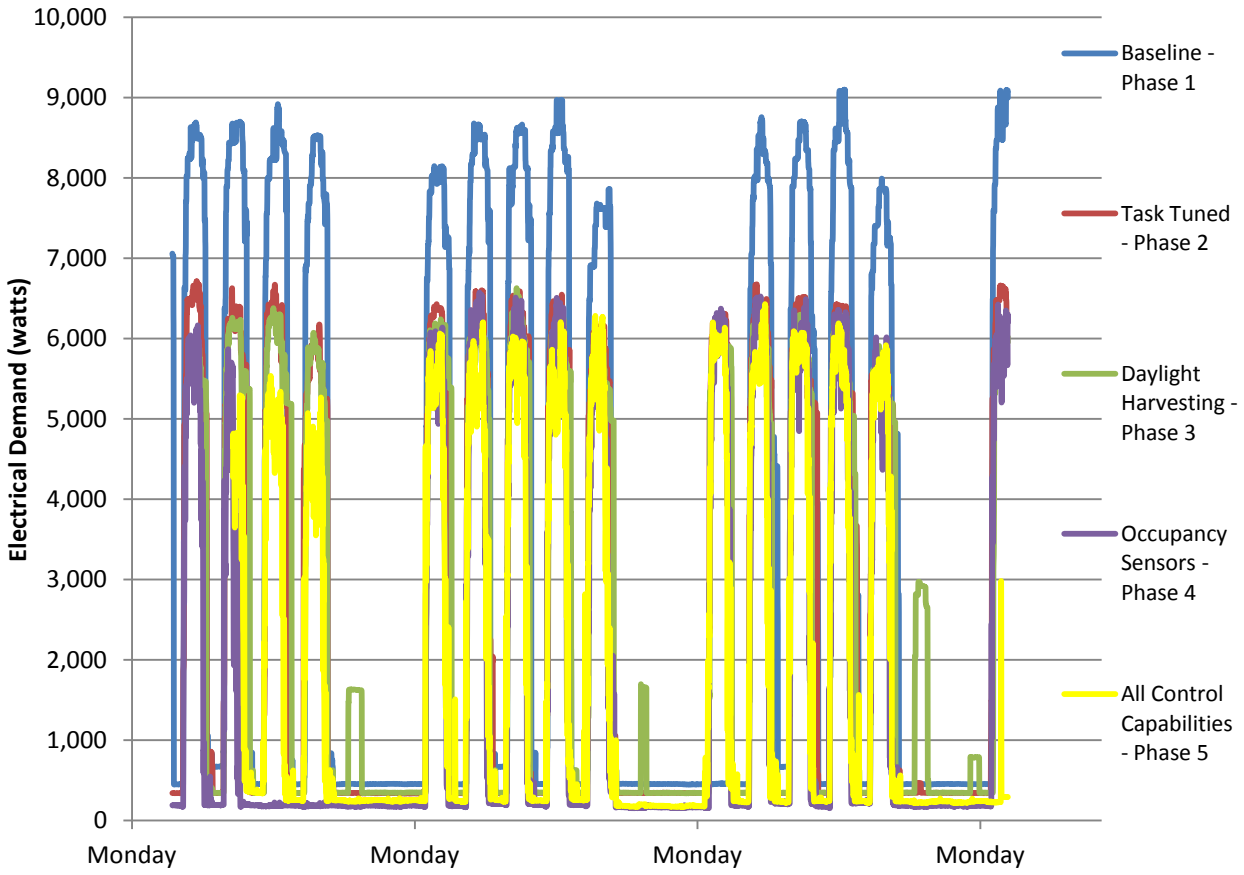


Chart From Appendix File: PS2500 all phases.xls, Sheet: PS2500 H3S All Phases

FIGURE 3. ALL PHASES, PANEL H3S: ELECTRICAL DEMAND (WATTS)

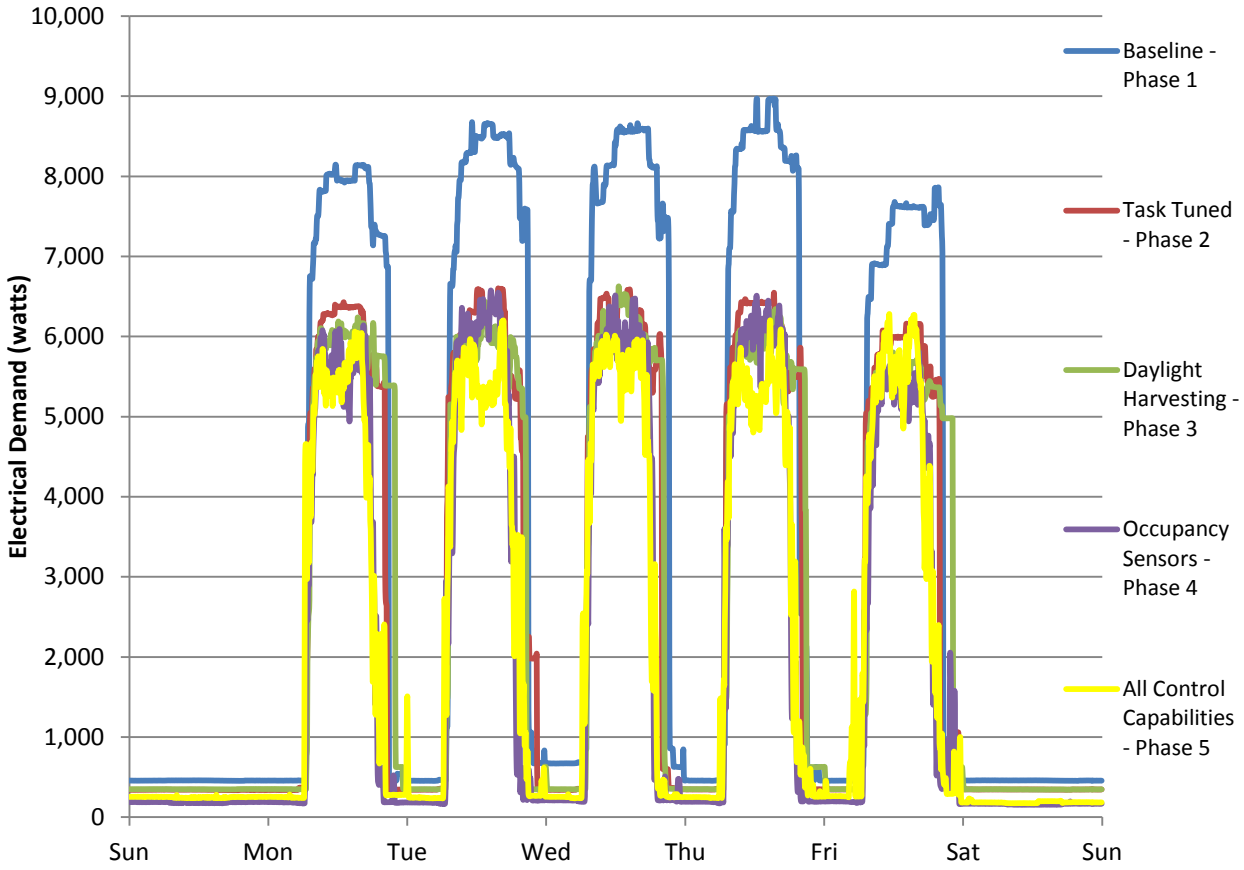


Chart From Appendix File: Typical Week (Normalized),xls, Sheet: Typical Week (Sat Normalized)

FIGURE 4. ALL PHASES, PANEL H3S: TYPICAL WEEK ELECTRICAL DEMAND (WATTS)

Phase 1: Baseline

The baseline for this project was all of the fixtures operating at full power with manual on/off control only (the ALCS control features were disabled). The electrical demand during Phase 1 appears in Figure 5.

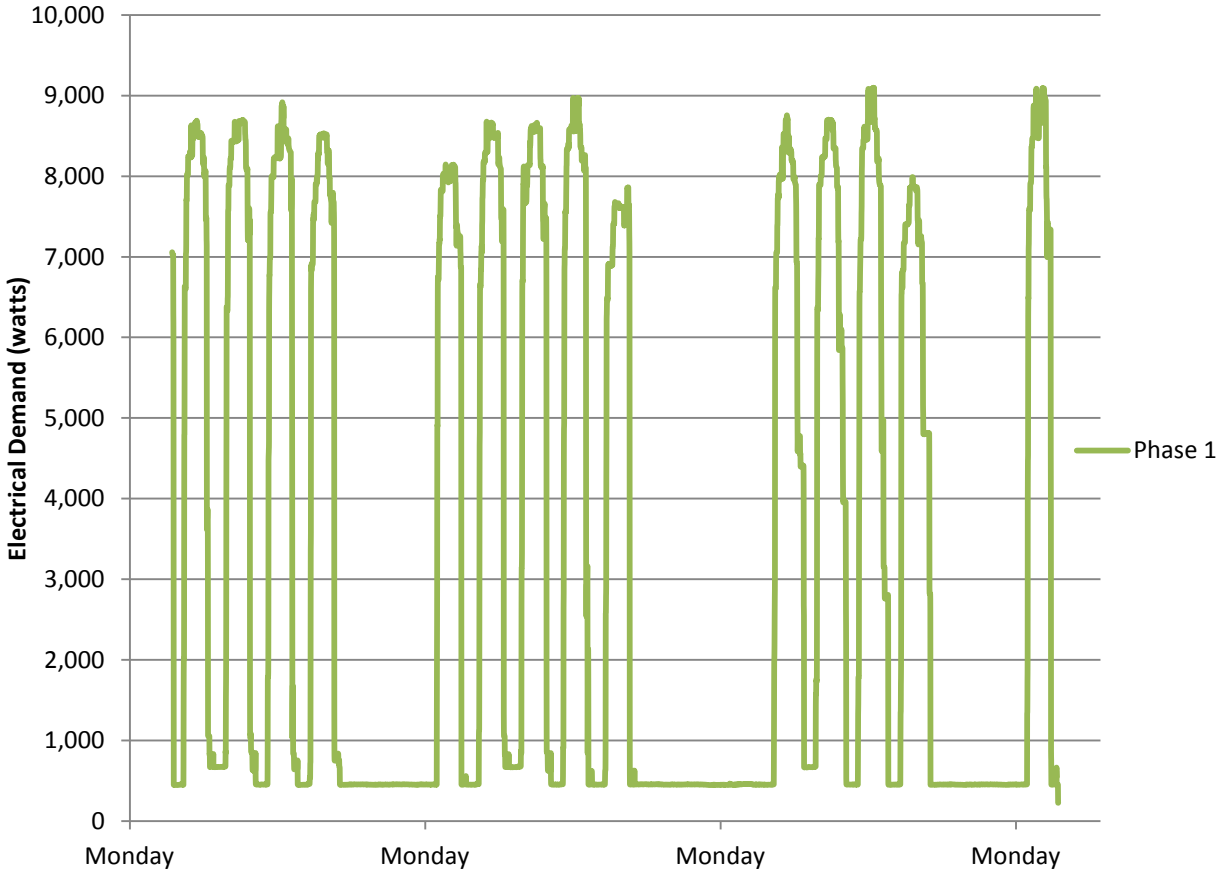


Chart From Appendix File: PS2500 & T&D data Phase 1.xls, Sheet: H3SR Baseline Chart (Phase 1)

FIGURE 5. PHASE 1, PANEL H3S: ELECTRICAL DEMAND (WATTS)

Phase 2: Task-Tuned Fixtures

The fixtures were initially tuned down to approximately 85% to 90% of full power. Approximately 7 to 10 days later, the fixtures were tuned down again to approximately 70% to 80% of full power. One area, noted as A1 in the Monitoring Plan and project floor plan, had its light level brought back up to the initial task-tuned level at the occupant's request. Since area A1 has only 4 fixtures, the effect on the overall project was negligible.

The energy savings associated with tuning the fixtures at this site, when compared to the baseline, was just over 26%. The electrical demand during Phase 2 appears in Figure 6.

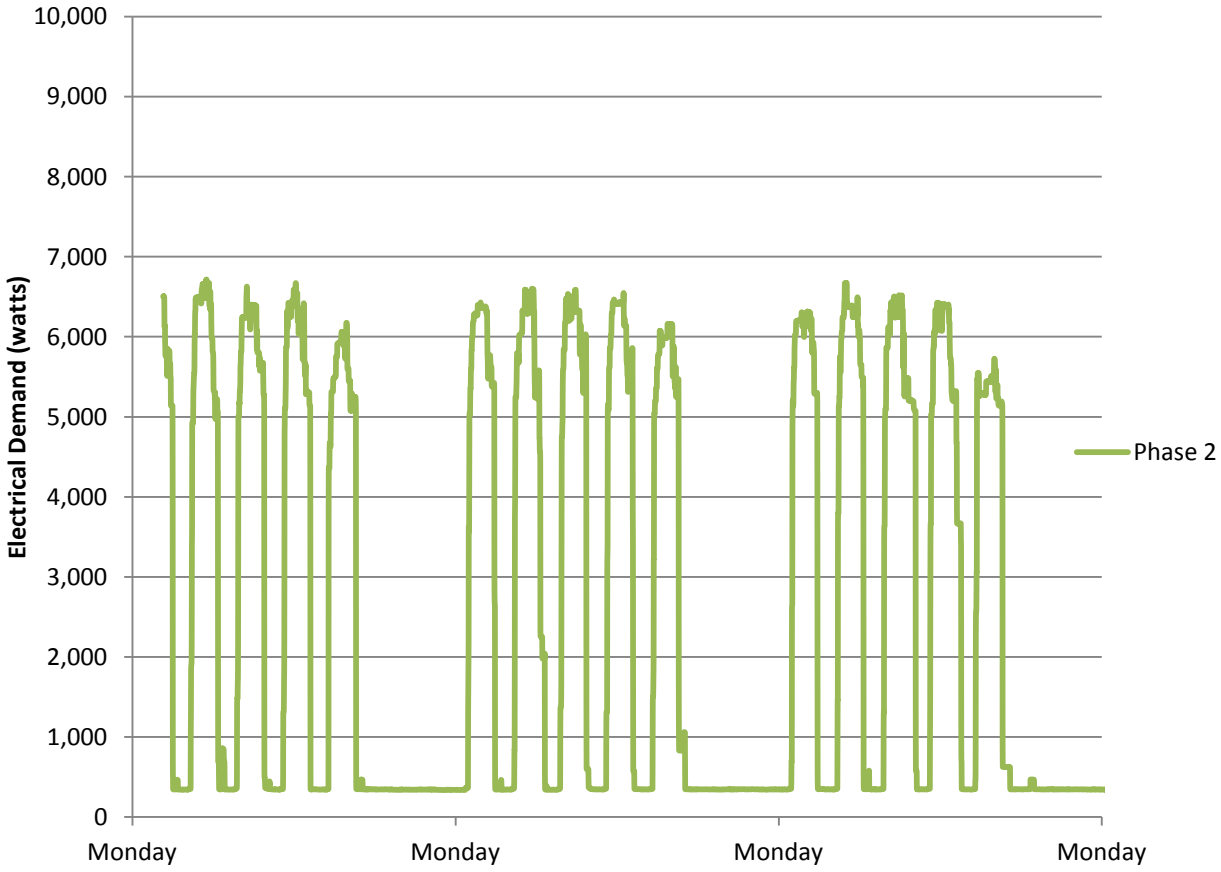


Chart From Appendix File: PS2500 & T&D data Phase 2.xls, Sheet: H3S Phase 2 Chart (Task-tuned)

FIGURE 6. PHASE 2, PANEL H3S: ELECTRICAL DEMAND (WATTS)

Phase 3: Daylight Harvesting

Phase 3 incorporated daylight harvesting control with the task-tuned level from Phase 2 as the maximum light level. During the site's typical occupied hours, 7:00 a.m. to 5:00 p.m., Monday through Friday, the ambient light sensing control strategy allowed the fixtures to dim to 20% minimum (not off). During other periods, the fixtures were allowed to dim to off if the ambient light levels permit.

The daylight harvesting control strategy resulted in an additional 2% savings from the task-tuned period, Phase 2. These nominal daylight savings are attributed to monitoring during a winter period (October–November), occupants having control of the window blinds, and the majority of the third floor south area not being directly impacted by daylight.

The electrical demand during Phase 3 appears in Figure 7.

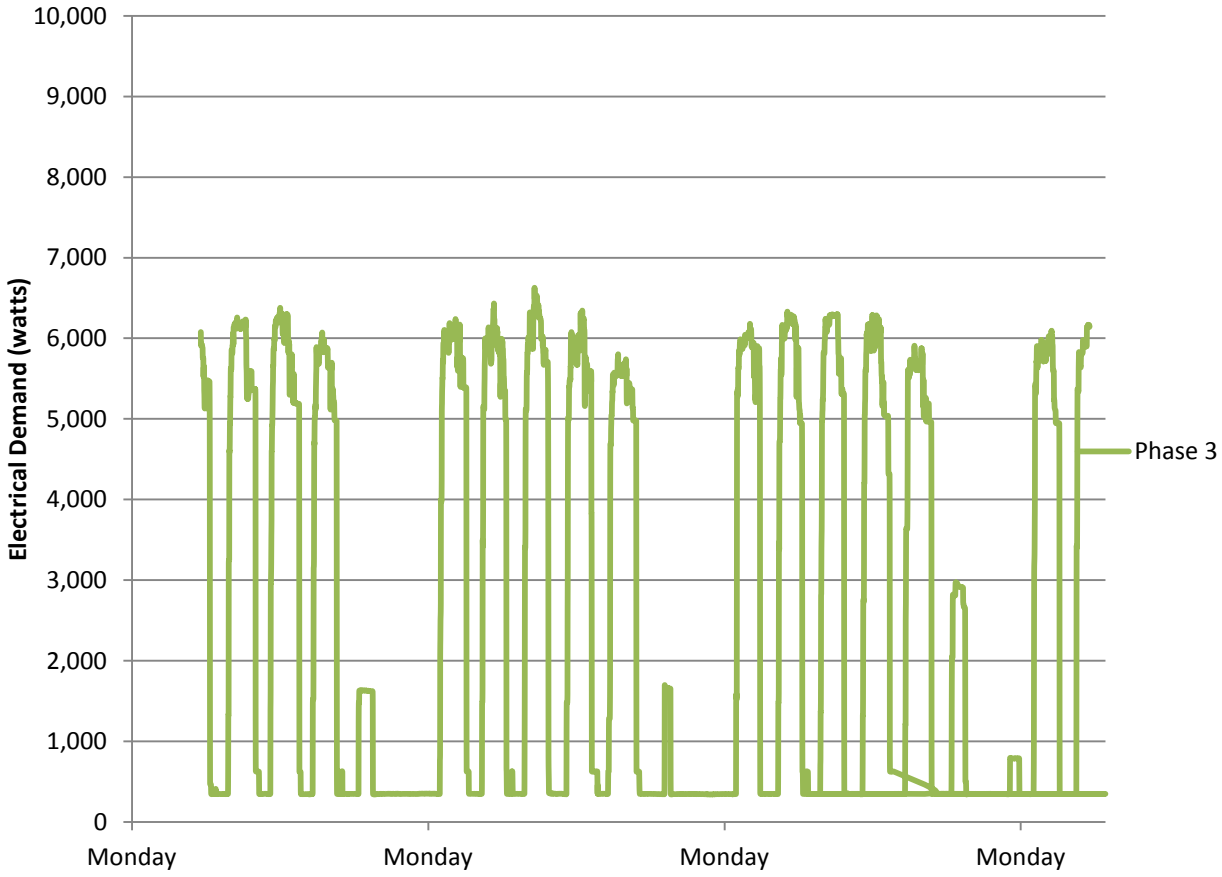


Chart From Appendix File: PS2500 & T&D data Phase 3.xls, Sheet: H3S Phase 3 Chart (Daylight)

FIGURE 7. PHASE 3, PANEL H3S: ELECTRICAL DEMAND (WATTS)

Phase 4: Occupancy Sensor Control

In Phase 4, occupancy sensor control was implemented and daylight harvesting was disabled. The maximum light output was capped at the task-tuned level. Enlighted's occupancy sensor control strategy dimmed the fixtures to 20% of the tasked-tuned level after 8 minutes of no occupancy. If the area remained unoccupied for 6 more minutes, then the fixtures were shut off completely.

The occupancy control strategy resulted in an additional 22% savings when compared to Phase 3. The electrical demand during Phase 4 appears in Figure 8.

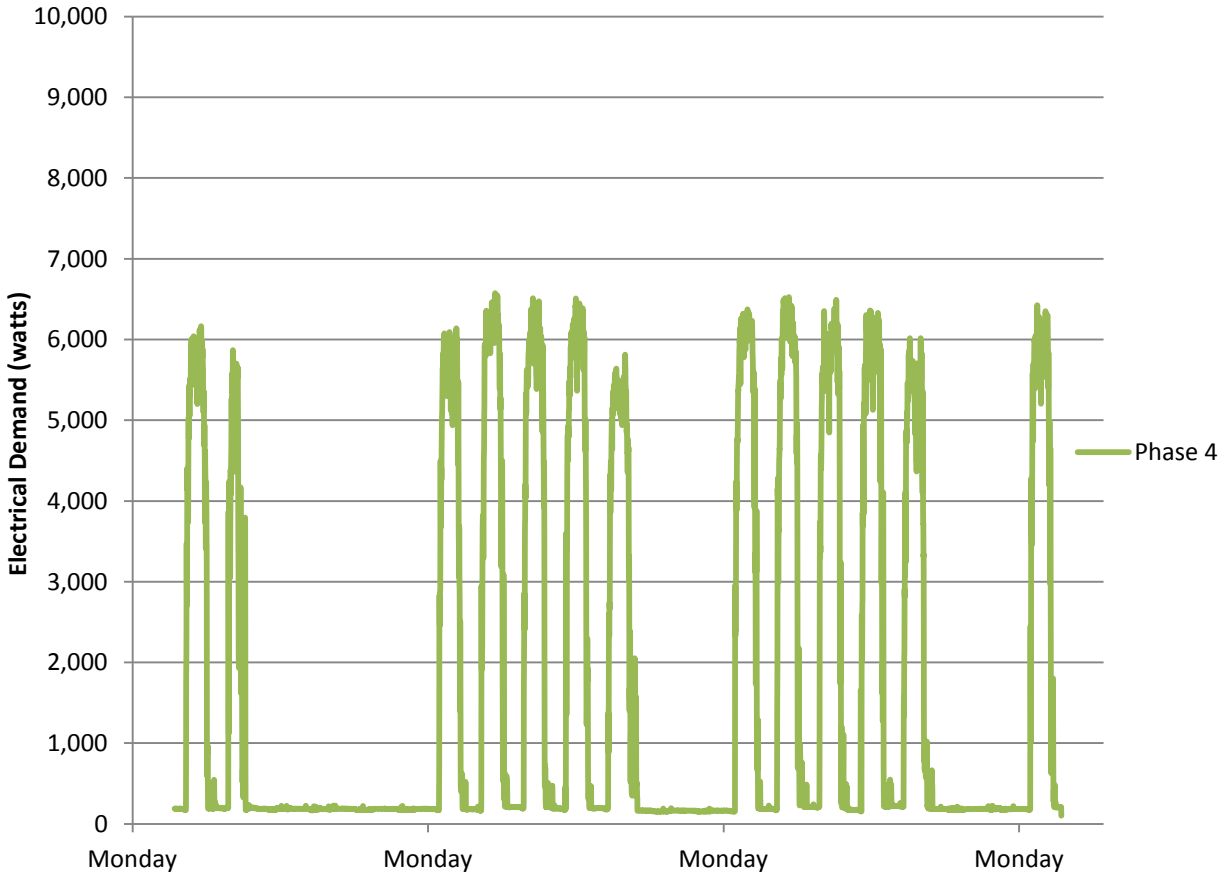


Chart From Appendix File: PS2500 & T&D data Phase 4.xls, Sheet: H3SPhase4Chart(OccupancySensor)

FIGURE 8. PHASE 4, PANEL H3S: ELECTRICAL DEMAND (WATTS)

Phase 5: Full ALCS Functionality

In Phase 5, daylight harvesting was again implemented, providing full ALCS functionality. However, implementing daylight harvesting control resulted in minimal savings when compared to Phase 4. For the reasons described above in Phase 3, the daylight impact on energy savings was nominal.

The increase in savings was less than 1% between Phase 4 and Phase 5. The electrical demand during Phase 5 appears in Figure 9.

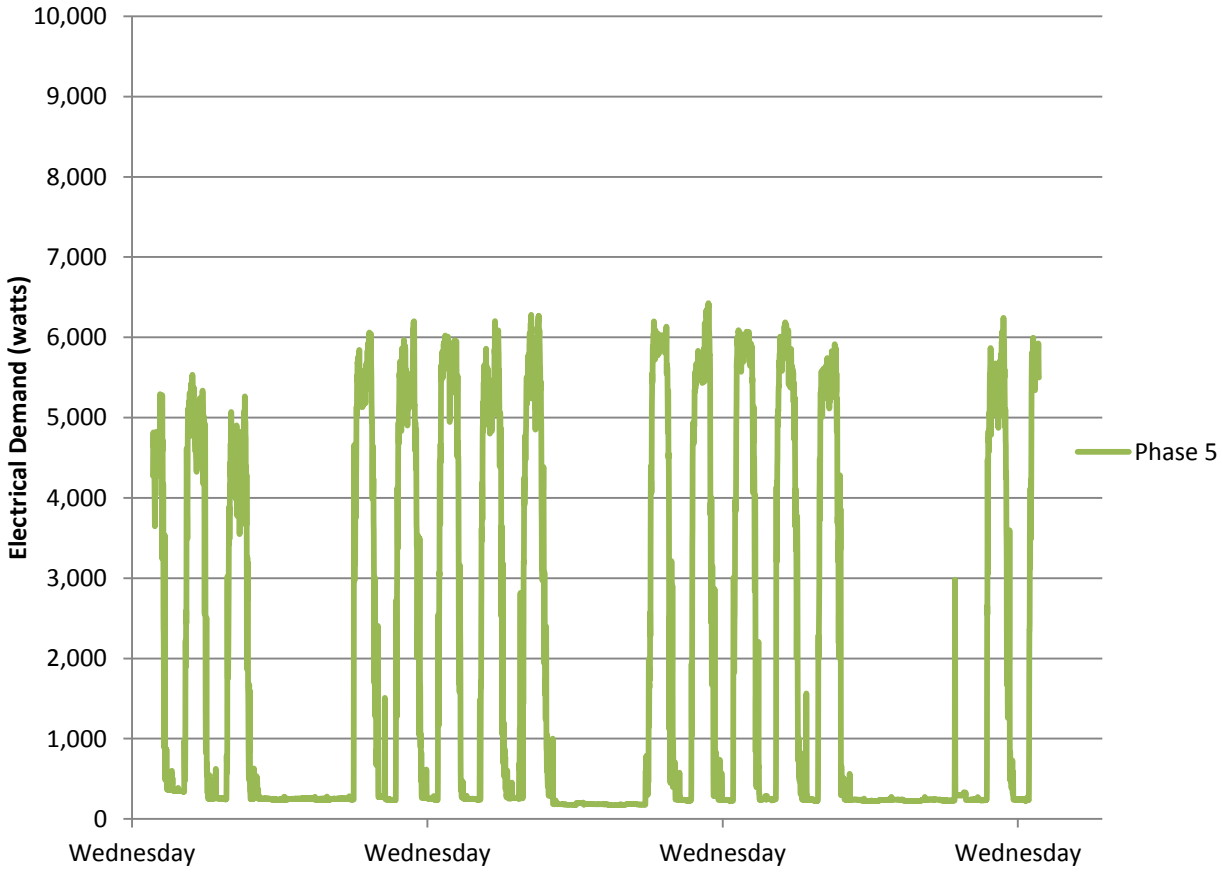


Chart From Appendix File: PS2500 & T&D data Phase 5.xls, Sheet: H3S Phase 5 Chart (Full ALCS)

FIGURE 9. PHASE 5, PANEL H3S: ELECTRICAL DEMAND (WATTS)

A typical office area which receives daylight (A5) is used as an example in Figure 10 of the decrease in energy consumption associated with implementing all controls, including daylighting.

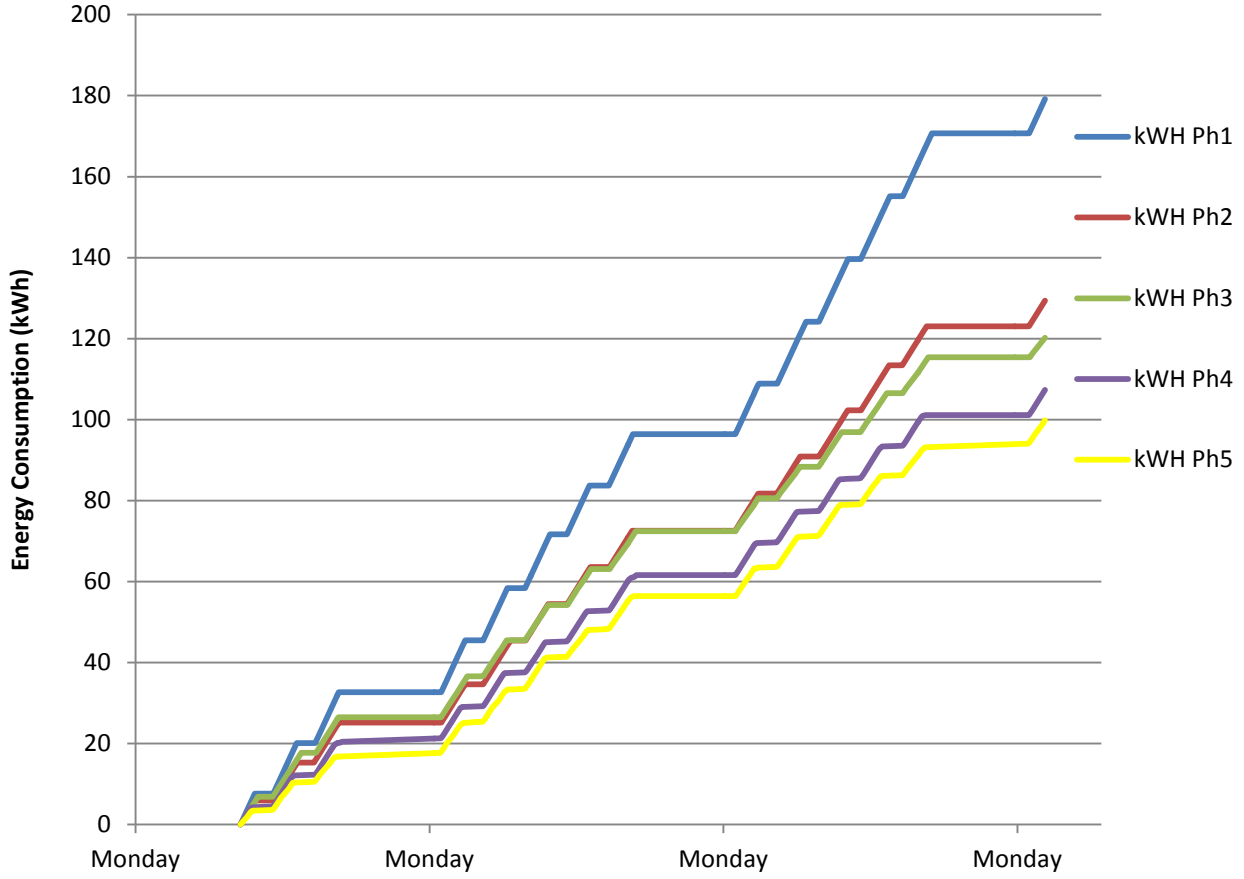


Chart From Appendix File: A5 Normalized (Elect Demand & Illuminance).xls, Sheet: A5 Cumulative kWh (Normalized)

FIGURE 10. OFFICE AREA WITH DAYLIGHT (A5) ALL PHASES (NORMALIZED) CUMULATIVE ENERGY CONSUMPTION

Figure 11 shows the illuminance levels for a typical office area which receives daylight (A5). The operating schedule has been normalized. The baseline, Phase 1, generally had the highest illuminance levels. Phase 5 had, on average, the lowest illuminance levels.

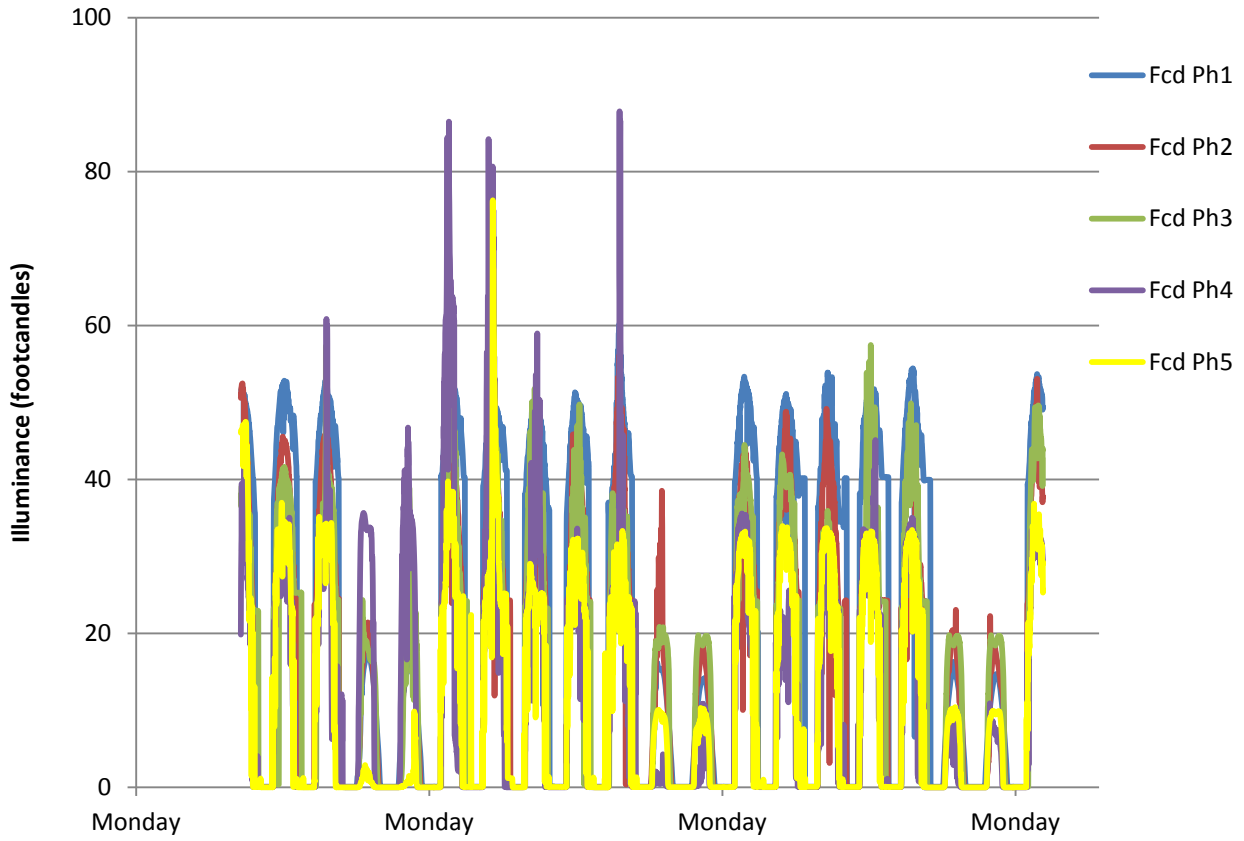


Chart From Appendix File: A5 Normalized (Elect Demand & Illuminance).xls, Sheet: A5 All Phases Illuminance

FIGURE 11. OFFICE AREA WITH DAYLIGHT (A5) ALL PHASES (NORMALIZED) ILLUMINANCE

DATA NORMALIZATION

Data was collected for five phases. Each phase consisted of 21 days during which a different lighting control strategy was implemented.

Almost every phase included an anomaly such as a holiday or Saturday work. It was necessary to normalize the data to show the electrical demand and energy consumption for typical periods of work from Monday through Friday with weekends off. To normalize the data, the average energy consumption (kWh) was calculated including only typical days of the week (for example, Mondays), excluding days with anomalies (for example, holidays). The average energy consumption on typical days was used in place of any anomalous data (for example, Saturday work). Energy consumption was summed for all 21 days of the monitoring period to calculate the normalized data.

The normalized data, the basic work year calendar provided by the CCCOE, and information regarding Saturday work, up to six Saturdays a year, were used to develop annualized energy consumption for each phase. The basic work year calendar shows that the CCCOE is typically open 238 days per year. The CCCOE is closed on 105 weekend days (which do not take into account unscheduled Saturday work) and on 22 weekdays (which include holidays, Fridays off, and winter break). Using the dates provided, the day of the week was determined for the days that the CCCOE is closed.

The average daily energy consumption values from the normalized monitored data were applied to the appropriate work days. Data that was recorded for the holiday and/or closed days during the monitored periods was applied to the typical 22 holiday/closed weekdays. The three days of Saturday work that were captured during the Phase 3 monitoring period, which showed 2.14 times more energy consumed on a work Saturday than a non-work Saturday, were also used to develop annual energy consumption for each phase of controls.

COMPARATIVE ANALYSIS OF VENDOR DATA

POWER MONITORING METHODS

Data from the ALCS was recorded through the Enlighted Intelligent Lighting Control System, which consists of Enlighted Smart Sensors, Enlighted Powerpack/Control, Enlighted Gateway, and the Enlighted Energy Manager (EEM). Each fixture is equipped with an Enlighted Powerpack/Control and an Enlighted Smart Sensor. Each Enlighted Powerpack/ Control unit contains a utility grade metering chip, Teridian 78M6613, which continuously monitors the electrical demand at each fixture. (For product specifications, see Appendix D). Data is wirelessly sent back to the gateway and then on to the EEM where the data is monitored, recorded, and reported.

VENDOR DATA SET

Enlighted provided four days of raw 5 minute interval data from the EEM. The data is comprised of total power readings from all 162 fixtures. The data collection period was December 3 through December 7, 2012.

COMPARATIVE ANALYSIS

The data from the ALCS was compared with the monitored data from the same 4 day period. Overall the two sets of data track each other closely and show a total accumulated energy consumption within 2%. There are some fairly significant differences in the recorded data early in the morning and again in the evening. The differences are most likely because Enlighted's EEM has a slightly different time stamp than the power loggers which were installed by EMCOR. Typically, when occupancy stabilizes at a normal level later in the day, the discrepancies between the two sets of data are within 2% or less.

Graphic comparisons of the data sets are provided in Figure 12, Figure 13, and Figure 14. In the figures, data from the ALCS is labeled Enlighted. The monitored data is labeled EMCOR.

CONCLUSIONS AND RECOMMENDATIONS

The close comparative results suggest the possibility of using an ALCS equipped with onboard/built-in power and energy monitoring capabilities to validate the savings associated with the installation of an ALCS. The level of savings validation that ALCS equipment can provide may be adequate for a variety of purposes, including potentially supporting savings claims for utility incentive programs.

However, the limited nature of this comparative analysis (4 days worth of data) suggests that additional data be gathered and compared. It is recommended that parallel data collection (traditional power monitoring and on-board ALCS monitoring) be included in follow-up studies involving other ALCS equipment vendors.

If additional data gathering and analysis yield favorable results, utilities could then develop specifications for ALCS monitoring and reporting equipment to verify long-term savings.

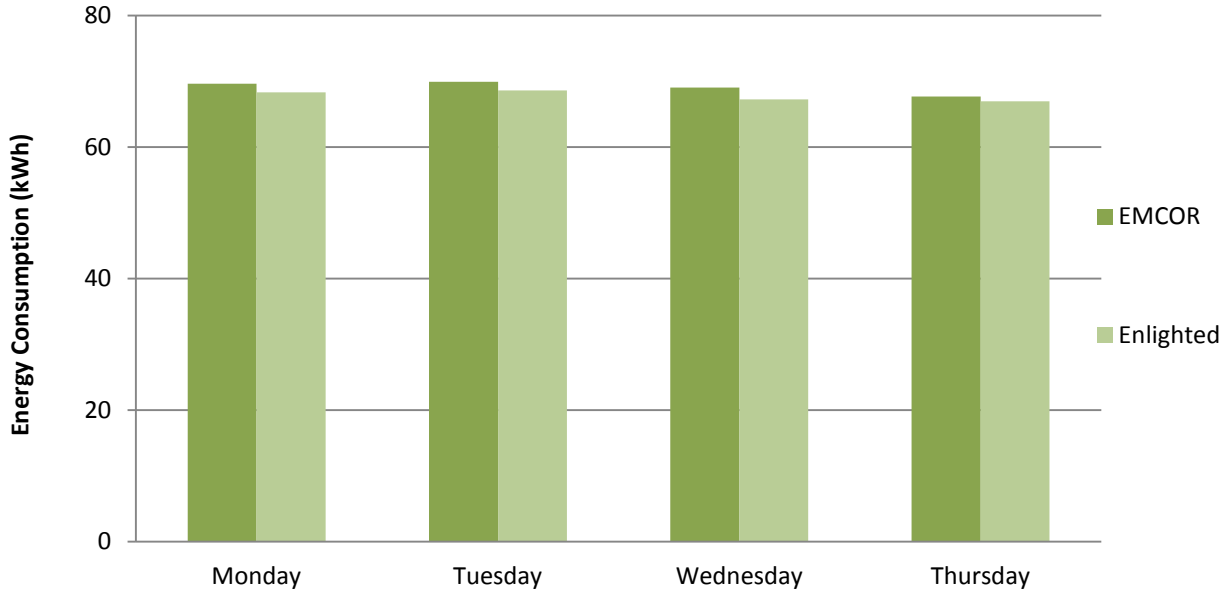


Chart From Appendix File: EES_Enlighted data comp.xlsx, Sheet: Daily Comparison (kWh)

FIGURE 12. ENERGY CONSUMPTION FOR THE COMPARISON PERIOD (ALL FIXTURES)

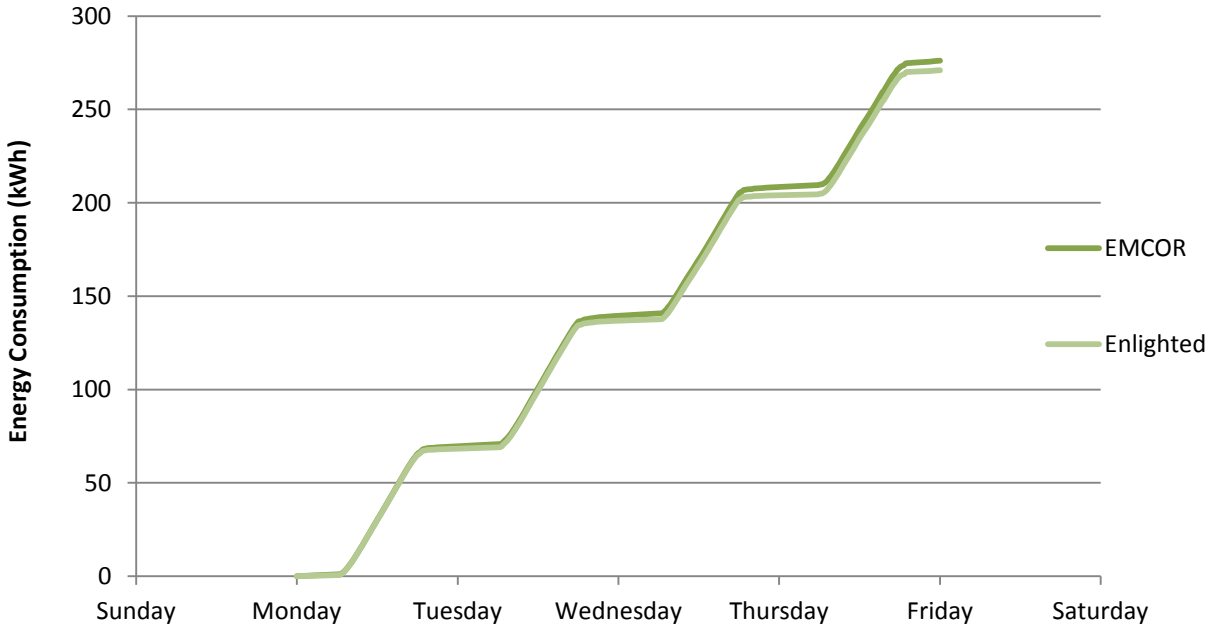


Chart From Appendix File: EES_Enlighted data comp.xlsx, Sheet: kWh Aggregate

FIGURE 13. CUMULATIVE ENERGY CONSUMPTION FOR THE COMPARISON PERIOD (ALL FIXTURES)

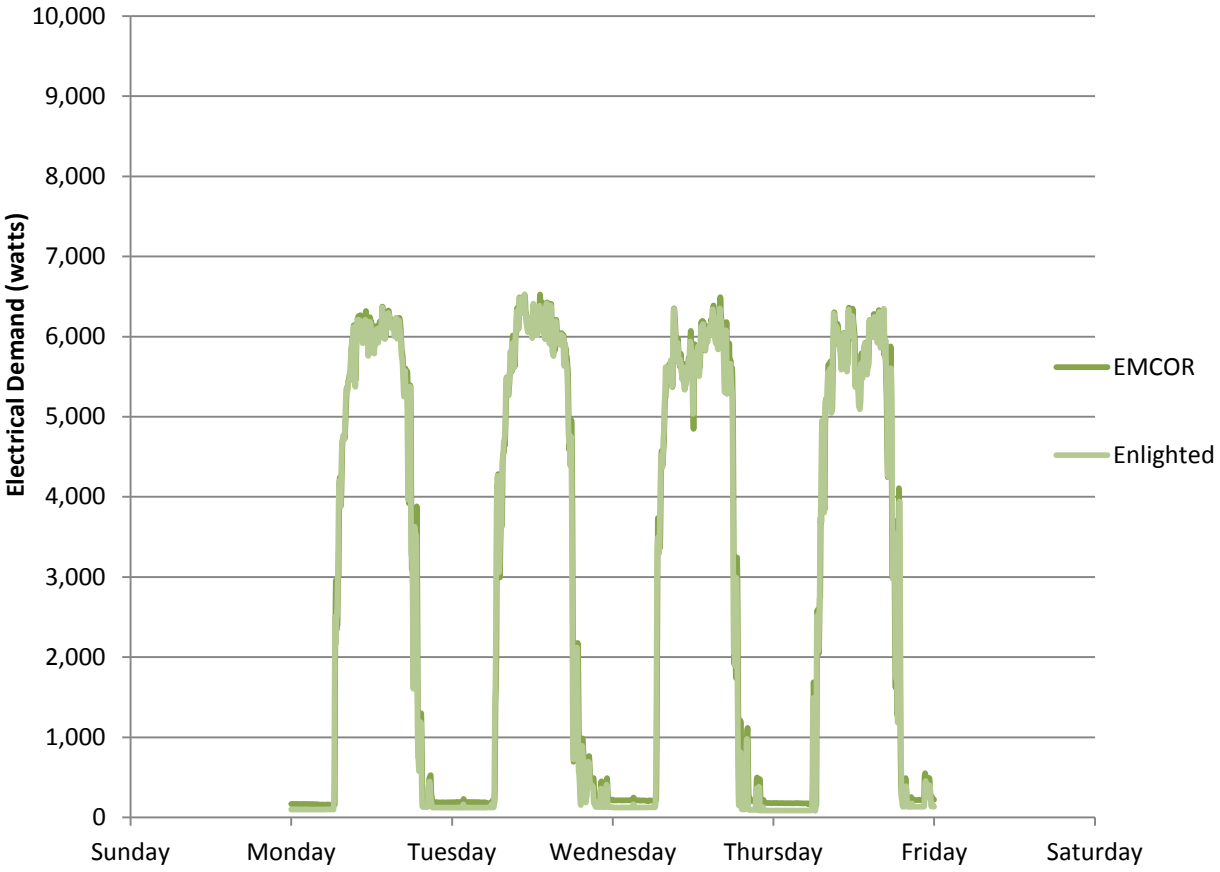


Chart From Appendix File: EES_Enlighted data comp.xlsx, Sheet: EES_Enlighted data

FIGURE 14. RAW POWER DATA PLOT FOR THE COMPARISON PERIOD (ALL FIXTURES)

EVALUATIONS

The findings from this study confirm that implementation of an ALCS can reduce lighting energy consumption. For each of the various control strategies evaluated, the lighting energy consumption was reduced as compared to the baseline case (no controls). The base cost of the wireless control system (Phase 2, to enable task tuning) is the most costly and is required for all follow-on phases. The incremental cost for each phase was essentially an artificial cost, the cost of configuring the next phase of the experiment. In an installation that is not a multi-phase study, this type of system would be likely to incorporate the full set of controls (task tuning and sensors) at the beginning, along with a comprehensive commissioning plan to enable them. Although periodic adjustments would be required, full cost and savings would result from a single phase implementation.

Beyond energy savings, other general benefits from use of an ALCS include optimization of natural light in the workspace and extended lamp life due to operation at dimmed levels and fewer annual operating hours. It is noted that user-level lighting control was not provided in this testing sequence as it was in another study, *LED Office Lighting and Advanced Lighting Control System*.[6] In the other cited study, incremental savings associated with user-level lighting control were not established, and it was unclear whether the user level control was seen as a value to the Class A office workers involved in that study.

In this study, based on seven post-retrofit occupant surveys, most of the participants were satisfied with the controls provided to them. The survey asked, "If you could change the lighting in your office, what would you do?" The most common response was, "I would not change anything."

A single comment was received indicating discomfort with the occupancy sensors, which switch off lighting in zones adjacent to where people are working, darkening the surrounding area. The surveys and responses are in Appendix G.

The installer reported that installation was simpler than installing fixtures without dedicated controls. He noted that "two ballasts failed after installation after evoking dimming for a few weeks. They flickered when dimmed too deeply." From the installer's perspective, the commissioning was a success because both facilities management and building occupants were involved in the commissioning process. The installer's comments are in Appendix G.

The wireless technology and associated components (sensors, controls) have been shown to be reliable, and they available through several manufacturers. Enlighted, for example, has been providing ALCS since early 2011 and has claimed over 5,000,000 ft² of lighting systems to be under control by their system.[7]

Wireless, digital network costs are decreasing rapidly, and sensors and controls are becoming more available. In this case, the installed controls cost approximately $27,000 (including the necessary dimming ballasts) to control 162 fluorescent fixtures. In the other cited study that investigated ALCS, the installed controls cost about $30,000 to control 53 LED fixtures, considerably more on a per fixture basis. Note that there is a base level of "fixed cost" for ALCS system architecture: servers, gateways, Ethernet cables, and switches.

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[6] EMCOR Energy Services (Nov. 30, 2012), *LED Office Lighting and Advanced Lighting Control System*. Emerging Technologies Program, Project Number ET11PGE3251. San Francisco: Pacific Gas and Electric Company.

[7] Kanellos, Michael (Nov. 8, 2012), *Enlighted Inc. Hits Major Milestone: Over Five Million Square Feet of Commercial Real Estate Now Under Management*. Press Release. Sunnyvale, CA: Enlighted Inc. http://www.enlightedinc.com/ourpress/enlighted-inc-hits-major-milestone/

Therefore, there is likely to be a threshold project size to achieve cost effectiveness. Projects with a large number of fixtures and those with a high initial lighting power density are apt to achieve a faster return on investment than smaller projects where the power draw is relatively low.

The wireless controls in the current study provided a simple payback period of approximately 13 years when compared using annualized energy savings at standard utility rates for a medium-sized commercial building. The other cited study was for a larger facility operating at a lower energy cost.

Based on the cost effectiveness of ALCS shown in this study, two conclusions follow: For new construction, few market barriers prohibit use of ALCS, beyond the indeterminate "threshold" project size needed to offset the cost of system architecture. For a retrofit, however, cost effectiveness can still be a significant barrier to use of the technology.

RECOMMENDATIONS

ALCS is recommended as a utility-approved energy savings measure for a variety of reasons: besides yielding proven energy savings, ALCS promotes increased flexibility in the configuration and tailoring of light levels based on user preference. Dimming through an ALCS can extend lamp and ballast life. Also, the ALCS configuration is well suited to implementation of a demand response program based on the ability to selectively dim lighting fixtures as needed from a central control point.

Typically, entities require that an energy project provide a simple payback period of five years or less in order to be considered for implementation.[8] Based on the simple payback period calculated for this study,[9] the costs must be mitigated to encourage these retrofits, at least during the current market transformation period. Utility incentives for ALCS could encourage more rapid market adoption.

A more aggressive task tuning approach should be considered as a way to increase overall savings. Task tuning (Phase 2) provides the most savings of any of the phases, as shown in Table 2. Implementation of occupancy sensors (Phase 4) produces additional significant savings. If more aggressive task tuning had been implemented (with each space individually tuned to user requirements or standard illuminance values), then the savings from task tuning would increase. The savings from daylighting and occupancy sensors might not vary by much from the levels measured in this study. However, increasing savings should not be pursued if the lighting quality is compromised and does not meet IES standards.

Admittedly, approximating the savings for an aggregate project is difficult, because few comprehensive ALCS projects have been implemented. Further refinement of the savings potential should be pursued, including a predictive approach and additional field studies.

Predictive. Savings estimates can be built up from well-documented studies of component projects. The further reduction for task tuning can be calculated as a further percentage reduction based on the changed input wattage. Energy savings for daylight controls are variable. Energy savings for occupancy sensors are given by utility studies and widely used by utilities in support of incentive programs. Savings for occupancy sensors, for example, are predicted on a percentage basis depending on space type.

Additional Field Studies. This project succeeded in demonstrating ALCS as an effective lighting solution and indicated a correlation between standard power monitoring procedures and the data captured by the ALCS controls. This correlation should continue to be studied; it is recommended that parallel data collection (traditional power monitoring and on-board ALCS monitoring) be included in follow-up studies involving other ALCS equipment vendors.

[8] "Projects with paybacks less than 3 to 5 years should be implemented. Projects with paybacks greater than 10 years are generally not cost effective." US Department of the Interior, http://www.doi.gov/greening/energy/upload/Calculating_Payback.doc

[9] The simple payback period associated with the implementation of fixture retrofit and controls for this study is between 12 and 13 years. The payback reflects project costs associated with relamping and ballasting the existing fixtures. However, this cost element may not always be necessary if existing fixtures are already equipped with compatible dimming ballasts.

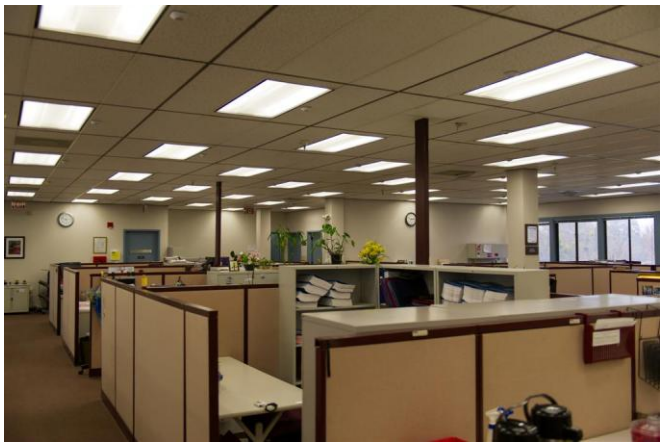
APPENDICES

APPENDIX A. SEQUENCE OF OPERATIONS

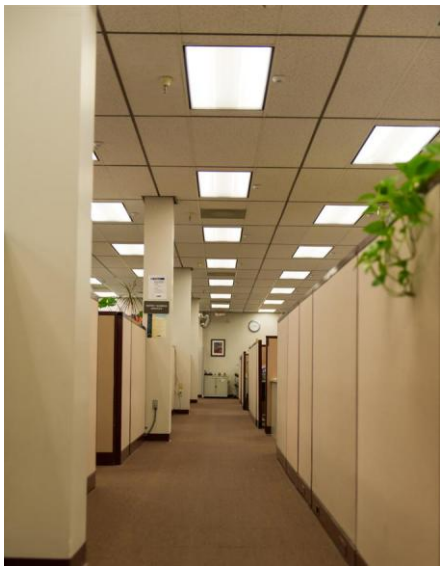
The sequence of operations had the following phases:

- Phase 1 – Fixtures operated at full power with only manual on/off control at the wall switches.
- Phase 2 – All fixtures were task-tuned to approximately 70% of full power.
- Phase 3 – Daylight harvesting control was implemented for the task-tuned fixtures. During normal operating hours the fixtures were now able to dim from the maximum task-tuned level to a minimum of 20% if enough daylight was entering the space. Outside of normal operating hours, the fixtures were able to go to full off if daylight permitted.
- Phase 4 – Occupancy sensor control was enabled for the task-tuned fixtures. The fixtures will now dim to 20% after 8 minutes of no occupancy being detected by the sensor and to full off after an additional 6 minutes of no occupancy.
- Phase 5 – Task-tuned + Occupancy sensor control (Phase 4) + Daylight Harvesting (Phase 3).

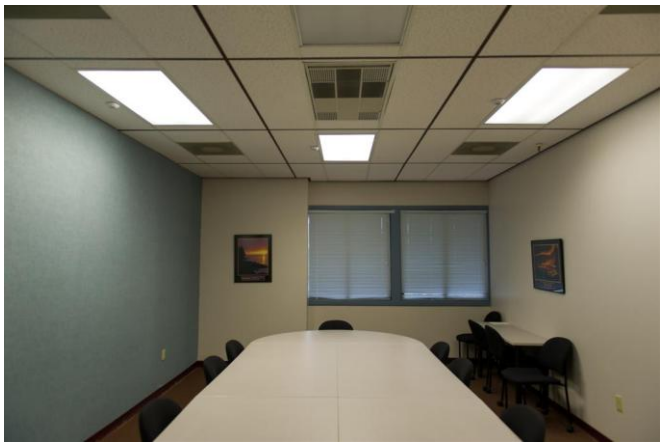
APPENDIX B. PROJECT PHOTOS



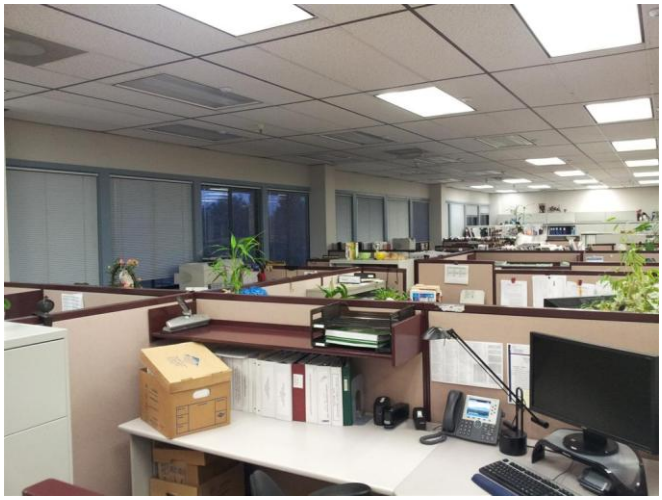
OVERVIEW PROJECT AREA 4100K-12



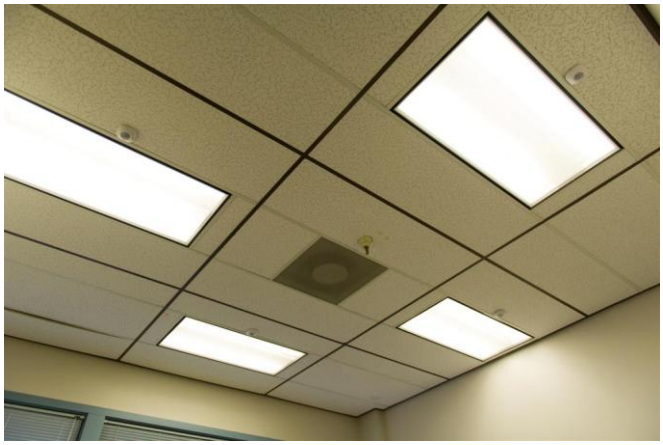
AISLE 4100K-22



CONFERENCE RM 4100K-6



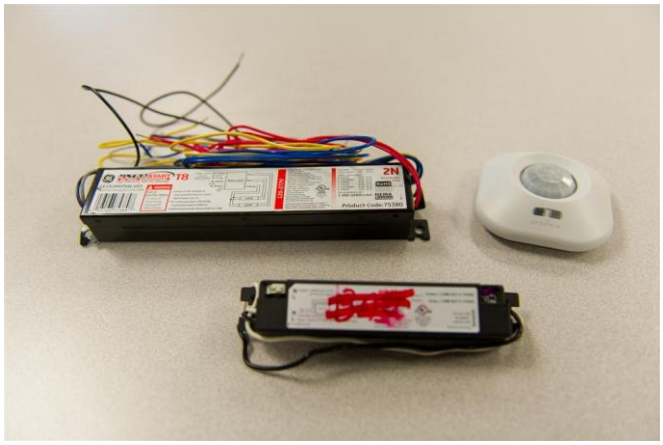
FIXT OFF BY OCC SENSOR



CEILINGSHOT FIXT&SENSORS 4100K-19

SINGLE FIXT&SENSOR 4100K-20

ENLIGHTED SMART SENSOR 4100K-2



BALLAST&ENLIGHTED SMART SENSOR&CONTROL 4100K-5

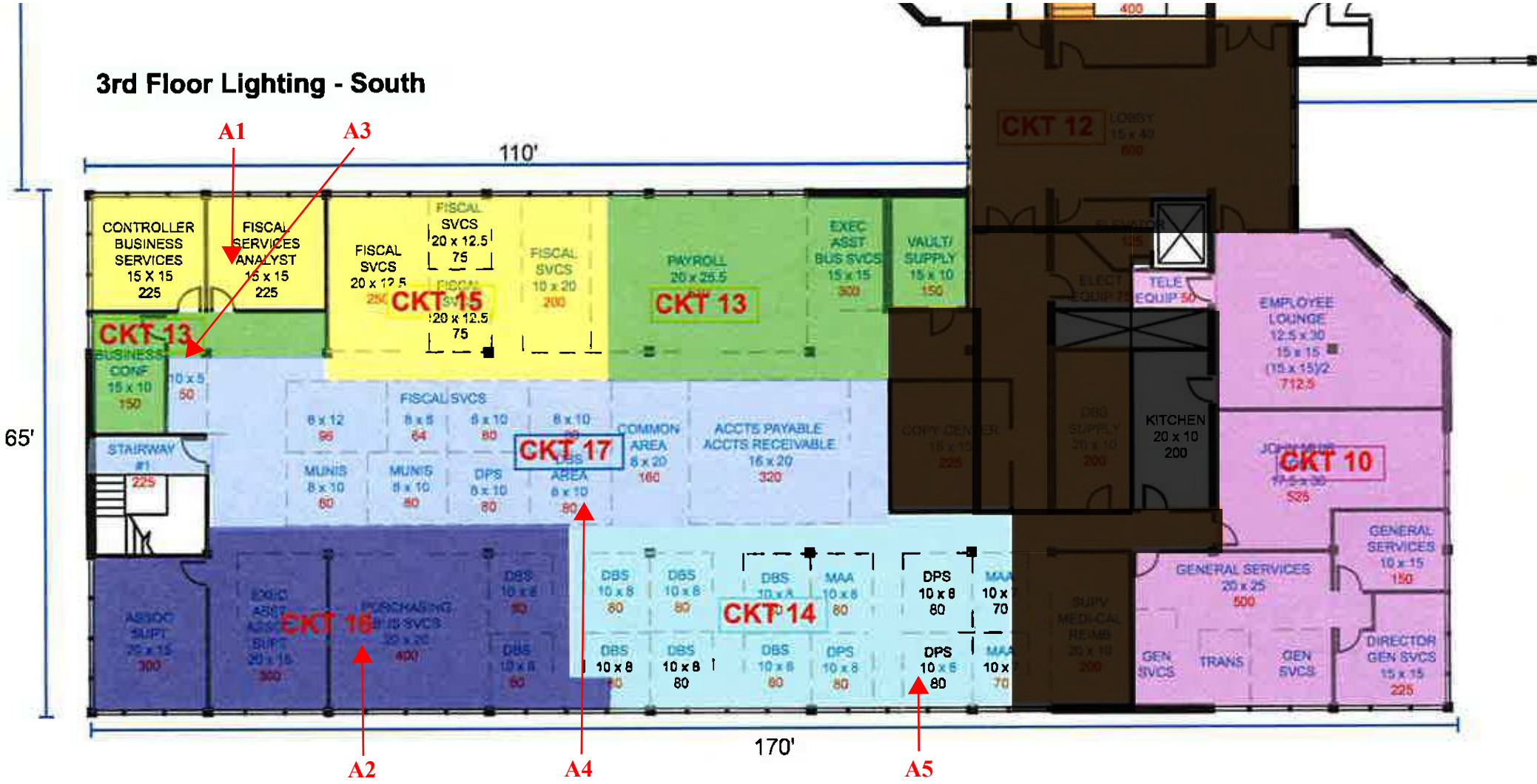
EEM 4100K-25

SWITCH EEM ROUTER 4100K-23

POWER LOGGERS AUTO-26

ILLUMINANCE LOGGER 4100K-32

APPENDIX C. MONITORING PLAN



Project area excluded grayed out area (CKT 12)

Arrows A1 - A5 indicate approximate location of illuminance sensors

Contra Costa County Office of Education Building Power and Lighting Monitoring Plan

Background
PG&E is performing an evaluation of wireless lighting controls technology at the Contra Costa County Office of Education building located at 77 Santa Barbara Road in Pleasant Hill. A project area has been established consisting of a suite occupied by administration personnel, located on the third floor. The general lighting for the suite is currently provided primarily by 2' x 4' linear fluorescent fixtures recessed into a grid T-bar ceiling. Fixtures are powered by five 20 amp lighting circuits, fed from panel H3S. The project work scope involves retrofitting the existing fixtures with new electronic dimming ballasts and wireless controls, subject to various control strategies during the evaluation period.

Objective
The monitoring plan has been developed with the goal of measuring the electrical and lighting characteristics both for the base case and for the case of each control strategy.

Work Steps
To accomplish the monitoring objectives, the following measurement sequences are indicated for aggregate load measurement, work area load measurement, and work area lighting measurement. The monitoring timeline, target monitoring areas, and monitoring equipment are also described below.

Aggregate Load Measurement
The lighting load will need to be separated from any other load for the five circuits to be tested. This will require a final evaluation of the general lighting for the entire suite. For all fixtures discovered not to be subject to the project, spot measurements will be recorded for these fixtures for later use in data manipulation.

For the aggregated lighting load, data loggers will continuously measure and record the power, energy, power factor, current, and voltage in five minute sampling intervals.

Power measurements will be performed using Summit Technology PowerSight PS2500 Power Loggers (PS2500 1–2) equipped with the line to DC option to be fed from the monitored circuit, which will be directly connected to the five circuits using 100 amp current transformers (CTs) and voltage leads. PS2500 1–2 will be located in the server room in or next to panel H3S. All exposed connections will be concealed within the panel.

Work Area Load Measurement
A total of five distinct work areas will be monitored: two private offices, two open offices, and a non-daylight area. For test area details, including base and test case lighting, see “Targeted Monitoring Areas” below.

For the light fixtures which serve each of the five work areas, data loggers will continuously measure and record the power, energy, power factor, current, and voltage in five minute sampling intervals.

Power measurements will be performed using Summit Technology PowerSight PS2500 Power Loggers (PS2500 3–7). In the case of the private offices, PS2500 units will be directly connected via CT and voltage leads to the lead fixture (either at the fixture or

associated junction box) which serves the switched area. The same approach will be used in the open area and non-daylight space when possible. However, an alternate approach may be necessary depending on how the existing fixtures are switched. The actual approach for these areas will be determined during a site visit prior to the installation of the M&V equipment.

Work Area Lighting Measurement
For the base case and each test case, illuminance measurements will be performed at five minute intervals on a continuous basis at the primary workspace in each target work area. Instantaneous spot measurements of correlated color temperature (CCT) and illuminance will be performed on a weekly basis.

Designated measurement locations will be identified and noted as an addendum to this monitoring plan. Measurement locations will be marked in the field to simplify the repeatability of measurements.

Continuous illuminance measurements will be performed by five T&D TR-74Ui loggers. The measuring sensor will be placed on or as close as possible to the primary work surface without interfering with the work needs of area occupants. During the weekly data collection, loggers will communicate wirelessly over a short distance with a handheld data collection device.

Spot measurements will be performed using a Konica Minolta CL-200A. Designated measurement locations will be identified and noted as an addendum to this monitoring plan.

Monitoring Timeline
Three weeks of baseline data will be collected both at the circuit level as an aggregate load and individually in the 5 workstations selected. If the current system is found to have existing controls or loads that cannot be turned off, then the baseline data will be collected accordingly and the current conditions will be documented. Demand and energy savings will be determined based on the difference between existing and proposed controls.

After completing the baseline data collection, the measurements will be repeated to collect data on the test case fixtures and controls, based on the conditions below:

a. Individual fixture task tuning (duration three weeks)
b. Task tuned fixtures + Daylighting (duration three weeks): This test condition will add daylighting control to all fixtures. During typical weekday work hours (7:00 AM – 5:00 PM) the daylighting control will dim the controlled fixtures light output below the task tuned level (maximum) to a minimum of 20% light output when the level of daylight permits. During unoccupied hours, the daylight controls will be able to switch fixtures off completely.
c. Task tuned fixtures + Occupancy sensors (duration three weeks): This test condition will add occupancy control to fixtures in all spaces. The occupancy control will dim the controlled fixtures light output below the task tuned level (maximum) to a minimum of 20% light output during typical weekday working hours (7:00 AM – 5:00 PM). During unoccupied times, the occupancy control will completely switch the fixtures off.

d. Finally, all features enabled and a composite effect determined (duration three weeks).

Target Monitoring Areas
The five targeted workstations are as follows:

- One private office is located on the north side of the building (circuit 15, Fiscal Services Analyst) with north facing windows and 4 existing 2' x 4' recessed linear fluorescent fixtures. This area is denoted as A1 in Appendix 1.
- One open office is located on the south side of the building (circuit 16, Purchasing General Services) with south facing windows and 6 existing 2' x 4' recessed linear fluorescent fixtures. Depending on the fixture switching and wiring configuration for this area, it may not be possible to monitor all fixtures and a reduced selection may be monitored. This area is denoted as A2 in Appendix 1.
- One non-daylight area is located at the northwest end of the floor (circuit 13, outside of the Business Conference room). This area has 4 existing 2' x 4' recessed linear fluorescent fixtures. Depending on the fixture switching and wiring configuration for this area, it may not be possible to monitor all fixtures and a reduced selection may be monitored. This area is denoted as A3 in Appendix 1.
- Two open office areas consist of multiple cubicles with 2' x 4' recessed linear fluorescent fixtures. One of these open office areas is on the south side of the building and has several south facing windows. The other open office is located in the same open area adjacent to other cubicles in the interior area of the floor. It is proposed to monitor 4 - 6 fixtures serving an individual cubicle in each area. However, depending on the fixture switching and wiring configuration for these areas, it may not be possible to monitor only the fixtures serving a cubicle and an increased selection may be monitored. These areas are denoted as A4 and A5 in Appendix 1.

Equipment
The consultant has selected the following equipment:

- 7 PowerSight PS2500 Power Logger w/LDC4
- 14 PowerSight HA100 Clamp-on 100 amp Probes
- 5 T&D TR-74Ui Luminance and UV Data Logger
- 1 T&D TR-57DCi Wireless Data Collector
- 1 Konica Minolta CL-200A Chroma Meter Pkg.

Attachments

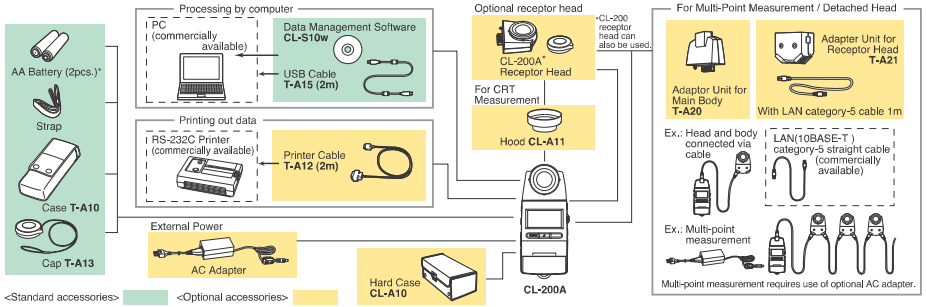
Appendix 1: Targeted Monitoring Areas
Appendix 2: Monitoring Instrumentation

Appendix 1 - Target Monitoring Areas

CONTRA COSTA COUNTY OFFICE OF EDUCATION
STEWART BUILDING
3rd Floor

Appendix 2 - Monitoring Instrumentation

SYSTEM DIAGRAM



*Not included as standard accessory in some areas.

Main specifications of Chroma Meter CL-200A

Model	Chroma Meter CL-200A
Luminance meter class	Conforms to requirements for Class AA of JIS C 1609-1: 2006 "Illuminance meters Part 1: General measuring instruments"
Relative spectral response	Closely matches CIE Standard Observer curves $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ Within 6% (fi') of the CIE spectral luminous efficiency $V(\lambda)$
Cosine response (f_2)	Ev: Within 3%
Receptor	Silicon photocell
Measuring function	Tristimulus values: XYZ Chromaticity: Evxy, Evu'v'; Ev, Dominant wavelength, Excitation purity Correlated color temperature: $E_vT_{cp}\Delta uv$; T_{cp}(JIS method; available only with CL-S10w) Color difference: ⊿(XYZ), ⊿(Evxy), ⊿(Evu'v'), ⊿Ev⊿u'v'(Target: 1)
Other function	User calibration function, Data hold function, Multi-point measurement (2 to 30 points)
Measuring range	0.1 to 99,990 lx, 0.01 to 9,999 fcd (Chromaticity: 5 lx, 0.5 fcd or above) in four automatically selected ranges (lx or fcd is switchable)
Accuracy*	Ev (Linearity): ±2%±1digit of displayed value xy: ±0.002
Repeatability*	Ev: 0.5%+1digit (2σ), xy: ±0.0005
Temperature drift	Ev: ±3% ±1digit of displayed value, xy: ±0.003
Humidity drift	Ev: ±3% ±1digit of displayed value, xy: ±0.003
Response time	0.5 sec. (continuous measurement)
Computer interface	USB
Printer output	RS-232C
Display	4-significant-digit LCD with back-light illumination
Operating temperature/ humidity range	-10 to 40°C, relative humidity 85% or less (at 35°C) with no condensation
Storage temperature / humidity range	-20 to 55°C, relative humidity 85% or less (at 35°C) with no condensation
Power source	2 AA-size batteries / AC adapter AC-308 (optional; for 1 to 10 receptors) or AC adapter AC-311 (optional; for 1 to 30 receptors)
Battery life	72 hours or longer (When alkaline batteries are used) in continuous measurement
Dimensions	69×174×35mm (2-6/16×6-14/16×1-7/13in.)
Weight	215g (7.6 oz.) not including batteries

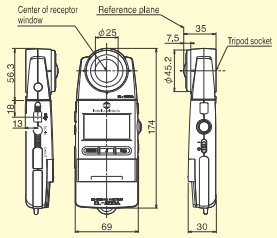
* 800 lx, Standard Illuminant A measured

Main specifications of Data Management Software CL-S10w

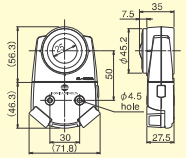
Type	Add-in for Excel® * Excel is required to use this add-in.
Operating environment	One of the following environments with Excel® installed: Windows® XP + Excel® 2003 (English, Japanese, or Simplified Chinese) Windows® 7 + Excel® 2010 (English, Japanese, or Simplified Chinese) * For details on system requirements for above versions of Windows® and/or Excel®, refer to their respective specifications. * Languages in parenthesis ( ) are the OS language. * Not compatible with 64-bit versions of Office 2010.
Compatible instruments	CL-200A, CL-200* * Some functions not usable with CL-200.

DIMENSIONS (Units:mm)

With receptor head attached to main body



With Adapter Unit attached to receptor head



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- Windows® and Excel® are trademarks of Microsoft Corporation in the USA and other countries.
- The specifications and drawings given here are subject to change without prior notice.
- Screens shown are for illustration purpose only.

SAFETY PRECAUTIONS

For correct use and for your safety, be sure to read the instruction manual before using the instrument.

- Always connect the instrument to the specified power supply voltage. Improper connection may cause a fire or electric shock.
- Be sure to use the specified batteries. Using improper batteries may cause a fire or electric shock.

Certificate No. : LRQ 0960094/A Registration Date : March 3, 1995
Certificate No. : JQA-5-80027 Registration Date : March 12, 1997

KONICA MINOLTA OPTICS, INC. Osaka, Japan
Konica Minolta Sensing Americas, Inc New Jersey, U.S.A. **Phone :** 888-473-2656 (in USA), 201-236-4300 (outside USA) **Fax :** 201-785-2482
Konica Minolta Sensing Europe B.V.

European Headquarter /BENELUX	Nieuwegein, Netherlands	Phone : +31(0)30 248-1193	Fax : +31(0)30 248-1280
German Office	München, Germany	Phone : +49(0)89 4357 156 0	Fax : +49(0)89 4357 156 99
French Office	Roissy CDG, France	Phone : +33(0)1 80 11 10 70	Fax : +33(0)1 80 11 10 82
UK Office	Warrington, United Kingdom	Phone : +44(0)1925 467300	Fax : +44(0)1925 711143
Italian Office	Milan, Italy	Phone : +39 02 39011.1	Fax : +39 02 39011.223
Swiss Office	Dietikon, Switzerland	Phone : +41(0)43 322-9800	Fax : +41(0)43 322-9809
Nordic Office	Västra Frölunda, Sweden	Phone : +46(0)31 7099464	Fax : +46(0)31 474945
Polish Office	Wroclaw, Poland	Phone : +48(0)71 33050-01	Fax : +48(0)71 734 52 10
Konica Minolta (CHINA) Investment Ltd. SE Sales Division	Shanghai, China	Phone : +86-(0)21-5489 0202	Fax : +86-(0)21-5489 0005
Beijing Branch	Beijing, China	Phone : +86-(0)10-8522 1551	Fax : +86-(0)10-8522 1241
Guangzhou Branch	Guangdong, China	Phone : +86-(0)20-3826 4220	Fax : +86-(0)20-3826 4223
Chongqing Office	Chongqing, China	Phone : +86-(0)23-6773 4988	Fax : +86-(0)23-6773 4799
Qingdao Office	Shandong, China	Phone : +86-(0)532-8079 1871	Fax : +86-(0)532-8079 1873
Wuhan Office	Hubei, China	Phone : +86-(0)27-8544 9942	Fax : +86-(0)27-8544 9991
Konica Minolta Sensing Singapore Pte Ltd.	Singapore	Phone : +65 6563-5533	Fax : +65 6560-9721
KONICA MINOLTA OPTICS, INC. Seoul Office	Seoul, Korea	Phone : +82(0)2-523-9726	Fax : +82(0)2-523-9729
Thailand Representative Office	Bangkok, Thailand	Phone : +662 361-3730 to 7	Fax : +662 361-3771

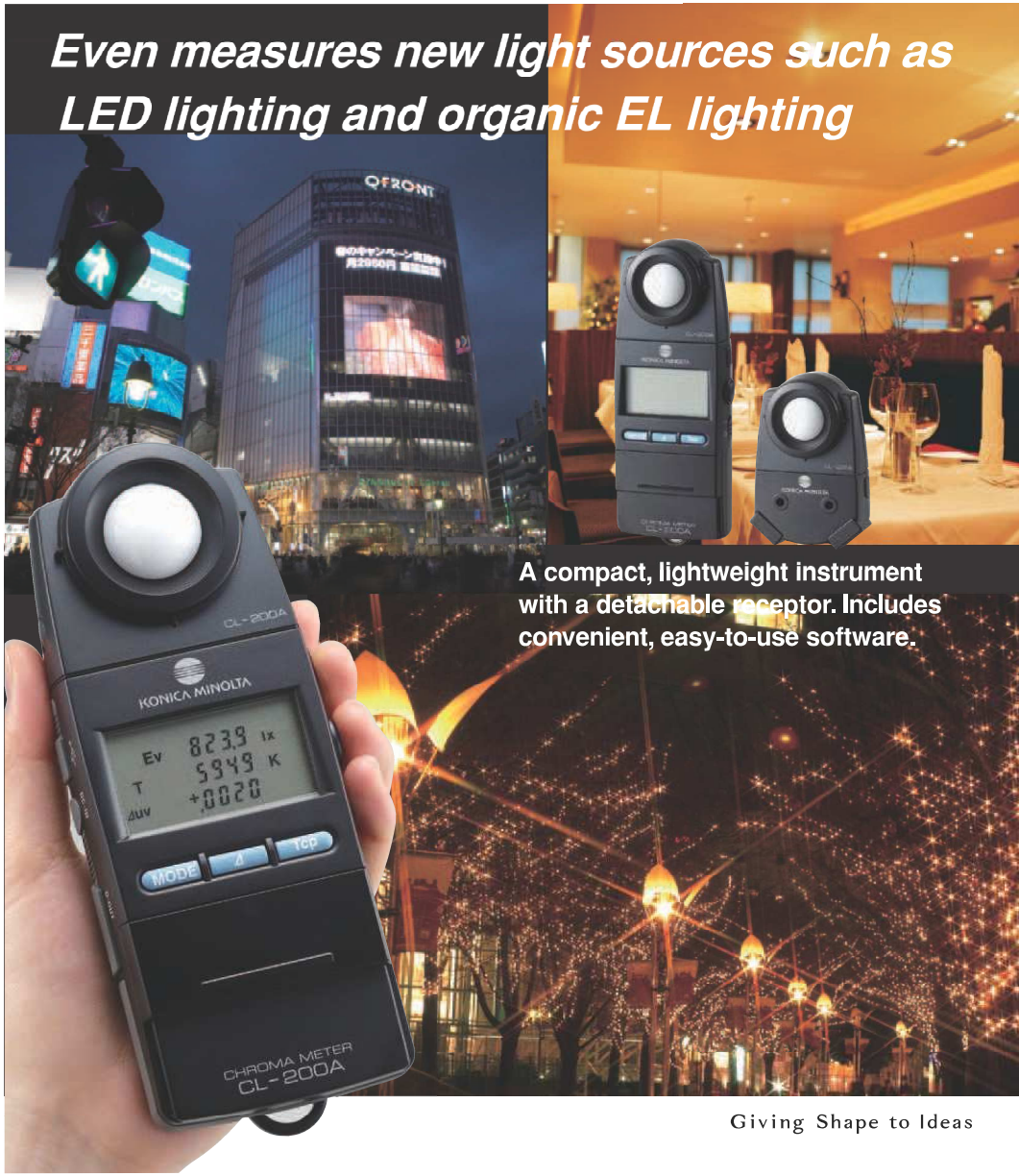
Addresses and telephone/fax numbers are subject to change without notice. For the latest contact information, please refer to the KONICA MINOLTA OPTICS Worldwide Offices web page : http://konicaminolta.com/instruments/about/network

9242-4876-12 BCDDPK⑤ Printed in Japan

KONICA MINOLTA

Ideal for measuring color temperature

Chroma Meter CL-200A



Giving Shape to Ideas

De facto industry standard for measuring color temperature!

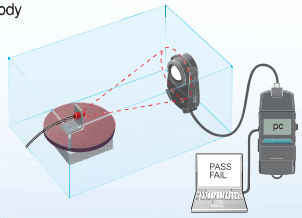
Compact and easy to carry

The CL-200A's compact body fits in your palm. Battery-powered so it can be taken along and used anywhere.

Detachable receptor head

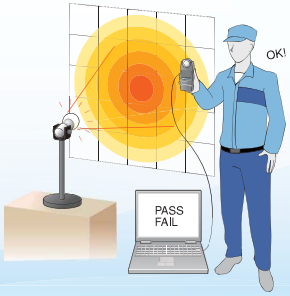
The receptor head can be detached and then connected to the main body using a normal LAN cable*, making it easy to install the sensor in an inspection system.

* Optional Adapter Units required for receptor head and main body



Data transfer using main body buttons

When using the CL-200A with Data Management Software CL-S10w (included), measurements can be taken and data transferred to Excel® using the main body buttons as well as computer keys.



Excel® add-in software included

Data Management Software CL-S10w (Standard accessory)

Easy, convenient Excel® add-in

Measurement data from the CL-200A can be transferred directly into Excel®. The transferred data can then be managed freely within Excel®.

Includes LED ranking function

Color variations, the top topic in the LED industry, can be quantified and a ranking function is also provided.

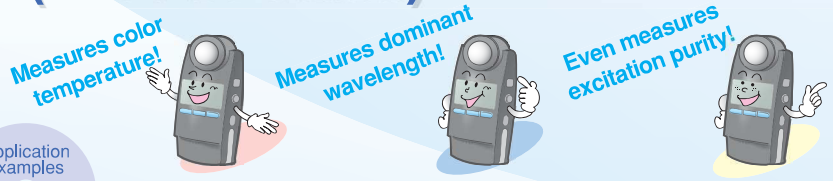
JIS correlated color temperature

Correlated color temperature is determined using the equations defined by JIS (Japanese Industrial Standards).

Multi-point measurement and user calibration also possible

Multi-point measurement management using up to 30 receptor heads is possible.
User calibration function enables compensation of measurement values to match a desired standard. Calibration can be performed by two methods: Single-point calibration or RGB calibration.

Can also measure illuminance (JIS AA class)



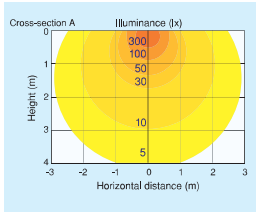
Application examples

For lighting production and adjustment

When using various types of light sources in a room or open space, it is sometimes necessary to check the color of the lighting.
By using the CL-200A, it is possible to adjust the lighting color so that the food in a restaurant looks delicious.

For evaluating light source characteristics

Evaluation of the light distribution of LED illumination modules or the illuminance distribution of lighting fixtures can be evaluated.



For color-viewing cabinet maintenance

A color-viewing cabinet like that shown at left is used in industries such as the printing industry to visually evaluate finished work under controlled conditions. This color-viewing cabinet provides illumination at a specific illuminance and color temperature by using fluorescent lamps, halogen lamps, etc. The CL-200A can be used for the daily maintenance and control of these lamps as well as to indicate when replacement is needed.

For projector light-source research and color inspection

The CL-200A can be used to measure the white balance and uniformity of microprojectors, etc. with internal LED light sources. The ability to connect multiple receptors using LAN cables enables measurement of not only a single point in the center, but up to a maximum of 30 points over the entire projected area.

For LED billboard development and maintenance

The CL-200A enables quality control of the LED modules for digital signage to be performed easily. If modules with different color tones are used together, the billboard will look mottled, but by measuring the chromaticity and color temperature of modules using the CL-200A and selecting modules based on measured values, billboard uniformity can be achieved.

For accurate measurements of color temperature, use the CL-200A!

Measurement accuracies of CL-200A and photographic color meter

When measuring light sources with non-continuous spectrums such as LEDs, etc., accurate illumination color temperature is particularly required. The CL-200A can measure color temperature accurately.

CL-200A

The CL-200A has sensors that closely match the color-matching functions defined by the CIE (International Commission on Illumination), enabling precise color measurement. The measurement results can be displayed in various color notations such as "Correlated color temperature and ⊿uv" according to the application.

Photographic color meter

In order to take more beautiful pictures, it is sometimes necessary to attach filters in front of the camera lens to compensate for the color of the light illuminating the subject. A photographic color meter is a meter used to select the appropriate filters, with the sensitivity of its sensors adjusted to match that of the film or digital camera sensor. In addition, because it uses photographic color temperature, which is calculated based mostly on the blue/red balance of the illumination, large errors may occur if it is used to measure light sources with non-continuous spectrums.

[Actual measurement data for daylight-color LED bulb]

	Measured color temperature	Color-temperature difference from standard-instrument measured value
Our company's standard instrument	5045	0
CL-200A	5011	-34
Photographic color meter	5600	555

Color temperature and correlated color temperature

Color temperature

When an ideal blackbody* is heated, it begins to emit light, and as the temperature increases the color of the emitted light changes from red to yellow to white. Since the color of the emitted light is determined by the temperature of the blackbody, the color of the light emitted by the blackbody can be expressed as the absolute temperature of the blackbody (in Kelvin). This color notation scale is called "color temperature". For example, a 7000K color would be the color of the light emitted by a blackbody heated to 7000K. Figure 1 shows the color of light emitted by a blackbody at various temperatures plotted on an xy chromaticity diagram. This curve is called the "blackbody locus"; "color temperature" expresses a color on this blackbody locus.

Correlated color temperature

Since the color of white light emitted by illumination equipment and displays is generally close to the blackbody locus, the color of such light sources is normally expressed using "color temperature".
However, the color of such light sources is not directly on the blackbody locus. Because of this, a way to enable similar color expression for colors within a larger region close to the blackbody locus was devised. This is called "correlated color temperature", and the larger region is shown by the isotherms on the xy chromaticity diagram in Figure 2.
To accurately express the correlated color temperature of a light-source color, it is necessary to state not only the correlated color temperature but the difference from the blackbody locus, normally in terms of ⊿uv.

*Blackbody
An ideal radiator. A body which completely absorbs all incident electromagnetic radiation. Although a perfect blackbody does not actually exist, coal is a familiar object that acts similarly.

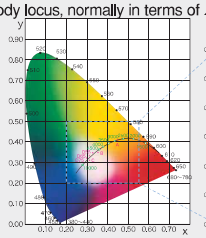


Figure 1: Blackbody locus on xy chromaticity diagram

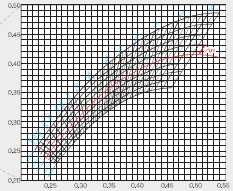
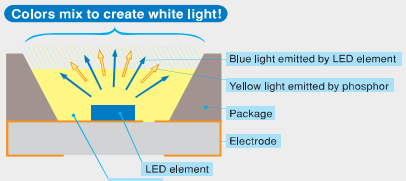


Figure 2: Closeup of blackbody locus on xy chromaticity diagram showing correlated color temperature region

General Reference Information
Measurements in the LED manufacturing process

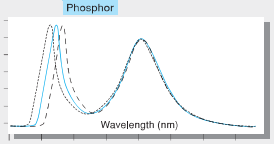
When made from blue LED and phosphor

The blue light emitted by the LED mixes with the yellow light emitted by the phosphor to create white light.



Problem:

Since the spectral emission distribution of the blue light emitted by the LED varies for each unit, variations in the resulting white light will occur. Since usually LED lamps use several LEDs, control of color mixing is necessary.



General solution:

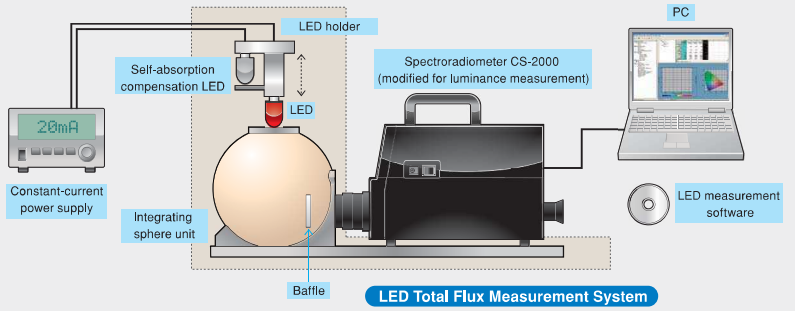
① Measure the spectral emission characteristics of each LED element and rank them accordingly.
② Measure the emission characteristics of the phosphor and rank accordingly.
③ Combine the ranked LED elements and ranked phosphor materials to achieve the desired white light.

④ Inspect the output light quality of the final assembled white LED lamp.

How the CL-200A can help:
The CL-200A can measure the chromaticity from the phosphor and also inspect the output light quality of the final assembled white LED lamp.

LED total flux measurement system

- This system combines our top-of-the-line Spectroradiometer CS-2000 modified for illuminance measurement with an LED total flux measurement adapter to create an LED measurement system that utilizes a spectral measuring instrument conforming to CIE 122-1996 as the receptor. The total flux emitted in all directions by the LED is diffused by the integrating sphere and received for measurement by the spectroradiometer.
- This system conforms to CIE 127:2007.
- Since the spectral response of the receptor matches the CIE spectral luminous efficiency function V(λ), there is no need to perform troublesome color correction.
- To enable accurate measurements, a self-absorption compensation function is provided to compensate for the reduction in integrating sphere output due to self absorption of the light source when it is lit inside the integrating sphere.



PS2500
Power Logger
"The Premier Power Logger"

Order Number:

[PS2500]

Complete power monitoring and analysis in a simple basic package.

- **SureStart™** *for getting great results*
  Uses artificial intelligence to verify that the wiring, connections, and setup parameters are correct. Information is available on the front panel display. This unique program (patent pending) reduces the time to hook up voltage and current probes and makes sure that all your measurements are correct.
- **SureSense™** *for accurate current*
  Uses automatic current probe identification to set the input of the PS2500 to match each current probe in use. This makes sure that the current probe readings are correct.
- **SurePower™** *for reliable logging*
  The meter's operation is backed up by rechargeable batteries and has an option to power it directly from the voltage being monitored. Current probes that normally require batteries get their power from the PS2500. This guarantees that the PS2500 will log power as long as you need it to with no part failing you.
- **Measures 140 different parameters**
  Volts, amps, watts, power factor, frequency, THD, etc. Minimums, maximums, averages, and present values. The PS2500 measures parameters every second, regardless of the recording rate. This guarantees that you will have a true view of all of the data when the job is done.
- **Four current and three voltage channels**
  This allows the PS2500 to directly measure all phases and neutral in single, two-phase, three-phase, split delta, 2PT/2CT, DC, 45-66 Hz, 360-440 Hz, just about any situation you will ever encounter.
- **Clear display**
  View voltage, current, true power, apparent power and true power factor summaries without the use of a laptop
- **Wireless Communications** with Bluetooth technology.
- **Industry's Highest Safety Rating,** 600V CAT IV for connection at the service entrance.
- **Provision for Removable Memory** with SD upgrade.
- **Compatible with our product line**
  Use the same software, current probes (AC/DC, 0.01 to 5000 amps), voltage probes (AC/DC, 1 to 15,000 volts), and accessories.

Availability

The PS2500 is available now. To order, specify **PS2500**. PS2500 includes software, voltage leads, AC charging unit, and soft carrying case (everything except current probes) for $ 1,495. PowerSight® products are manufactured in the USA and sold by Summit Technology, Inc.

For more information on our products contact:

Summit Technology Inc.
2717 N. Main St., Suite 15
Walnut Creek, CA 94597-2747

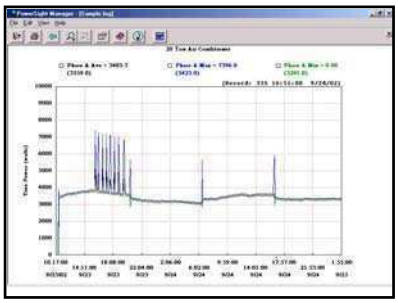
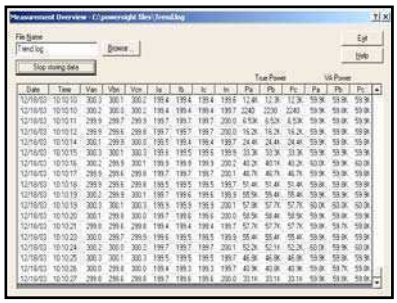
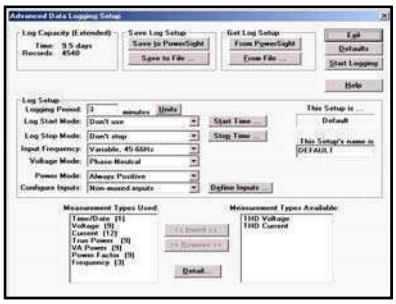
Voice: 1-925-944-1212
Fax: 1-925-944-7126
Email: sales@SummitTechnology.com

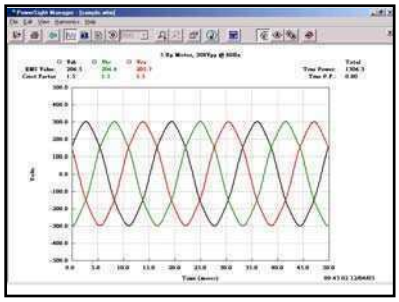
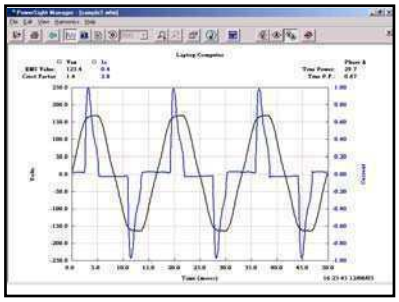
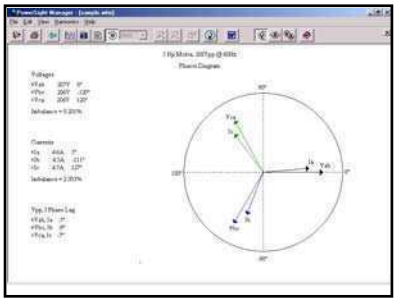
PS2500
Power Logger
"The Premier Power Logger"

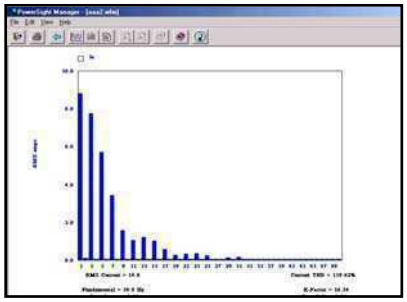
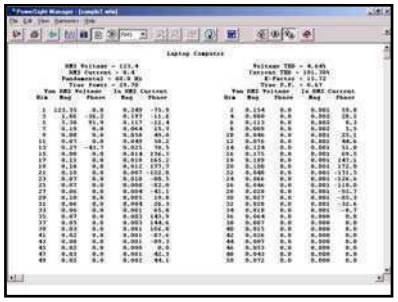
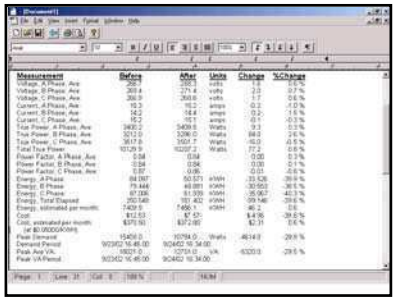
Order Number:

[PS2500]

PowerSight Manager Software (PSM) is a flexible, powerful, and easy to use power analysis software tool that is included with all orders for the model PS2500. It performs complete presentation and analysis of power consumption. Combined with our Report Writer software, it provides concise and compelling summaries including comparisons of performance.

Data Log Analysis	Data Trending	Custom Data Logging
		
Data Logs can be graphed/zoomed	Live Trend Data	Choose any of 60 variables

Waveform Analysis		Phasor Diagrams
		
Stored or Real-time Voltage and Current Waveforms		All Phase Relationships

Harmonic Analysis		Report Generation
		
Harmonic Contents as Graphs or Data		Choose any of 60 Variables

For more information on our products contact:

Summit Technology Inc.
2717 N. Main St., Suite 15
Walnut Creek, CA 94597-2747

Voice: 1-925-944-1212
Fax: 1-925-944-7126
Email: sales@SummitTechnology.com

100 Amp AC Current Probe

Order Number:

[HA100]

Summit Technology's HA100 Current Probe measures from 0.1 A_{RMS} to 100 A_{RMS} AC in a small form factor.

Specifications

- 0.1 to 100 Amps AC Current measurement

Accuracy

- +/- 2% of reading +/- 0.2 A_{RMS}

Dimensions

- Inside dimensions: 0.8 inch diameter
- Outside dimensions: 5.25 x 2.1 x 1.35 inches
- Cable length: 2 meters (6.5 feet).

Availability

The HA100 is available for immediate purchase from Summit Technology Inc. To order, specify **HA100**.

PowerSight® products are manufactured in the USA and sold by Summit Technology, Inc.

For more information on our products contact:

Summit Technology Inc.
2717 N. Main St., Suite 15
Walnut Creek, CA 94597-2747

Voice: 1-925-944-1212
Fax: 1-925-944-7126
Email: sales@SummitTechnology.com

Specifications

TR-74Ui Unit

Measurement Items	Illuminance	UV Intensity	Temperature	Humidity
Number of Channels	1 channel for each Measurement Item			
Unit of Measurement	lx, Klx	mW/cm²	°C / °F	%
Display Range of Cumulative Measurement	0 to 90,000,000 lx·h	0 to 62 W/cm²·h	–	–
Unit of Cumulative Measurement	Cumulative Illuminance: lx·h, Klx·h, Mlx·h	Cumulative Amount of Ultraviolet Light: mW/cm²·h, W/cm²·h	–	–
Refresh Interval	1 second (At a recording Interval of 1 second) 2 seconds (At a recording interval of 2 seconds or more)			
Recording Intervals	Select from 15 choices: 1, 2, 5, 10, 15, 20 and 30 seconds / 1, 2, 5, 10, 15, 20, 30 and 60 minutes *1			
Storage Capacity	Up to 8,000 readings (One reading is a set of data which includes Illuminance, UV Intensity, Temperature, and Humidity measurements.)			
Recording Modes	Endless / One Time			
LCD Displayed Items *2	Recording Status, Amount of Recorded Data, Communication Status, Recording Mode, Battery Life Warning, Current Readings (Illuminance / UV Intensity / Temperature / Humidity), Cumulative Measurements (Cumulative Illuminance and Cumulative Amount of Ultraviolet Light), Unit of Measurement			
Communication Interface	Wired: USB Communication, Serial (RS-232C) Communication Wireless: Infrared Communication			
Communication Time	When downloading 1 Unit of full data: USB Communication: about 45 seconds Infrared Communication: about 60 to 80 seconds			
Power	AA Alkaline Battery LR6 × 1			
Battery Life *3	About 6 months			
Dimensions / Weight of Main Unit	H55 × W78 × D18 mm (excluding protrusions) / about 62 g (including one AA battery)			
Operating Environment	Temperature: -10 to 60˚C / Humidity: 90%RH or less (no condensation)			

*1: For Illuminance and UV Intensity the average for the measured values taken during the recording interval are recorded, and for Temperature and Humidity the measured values at the instant are recorded.

*2: Up to four digits are valid for the Current Readings and Cumulative Measurements.

*3: Battery life varies depending upon the type of battery, the battery performance, the measuring environment, and the frequency of communication.

Illuminance UV Sensor ISA-3151

Measurement Items	Illuminance	Ultraviolet Light
Measurement Range	0 to 130,000 lx	0 to 30 mW/cm²
Measurement Resolution	Minimum: 0.01 lx	Minimum: 0.001 mW/cm²
Measuring Accuracy	10 to 100,000 lx: ±5% (At 25°C 50%RH)	0.1 to 30 mW/cm²: ±5% (At 25°C 50%RH) *1
Relative Spectral Response	Approximated to the CIE standard response function V (λ)	260 to 400 nm
Cosine Correction Characteristics (cos θ)	Within ±1.5% at 10°; Within ±3% at 30°; Within ±10% at 60°; Within ±30% at 80°	–
Operating Environment	Temperature: -10 to 60°C Humidity: 90%RH or less (no condensation)	
Storage Environment	Temperature: -10 to 60°C Humidity: 90%RH or less (no condensation)	
Conditions for Use	Do not expose to condensation, dampness, corrosive gases or organic solvents	
Sensor Dimensions	H23 × W65 × D12.6 mm	
Cable Length	1.5 m	

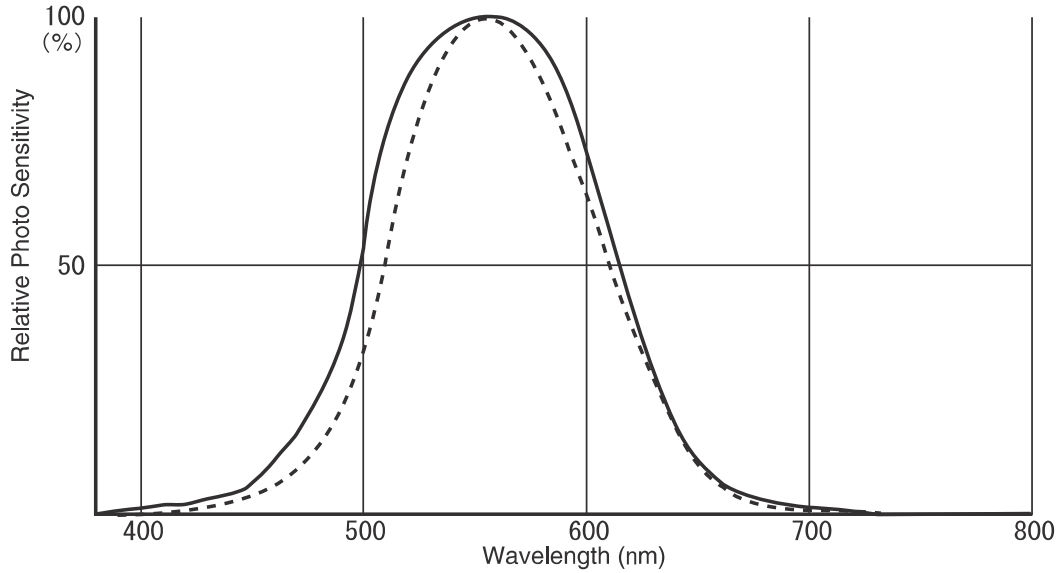
*1: Compared to the value measured by the T&D standard sensor for calibration under our calibration light source.

Temperature/Humidity Sensor THA-3151

Measurement Items	Temperature	Humidity
Measurement Range	0 to 55°C	10 to 95%RH
Measurement Resolution	0.1°C	1%RH
Measuring Accuracy	Avg. ±0.3°C	±5% (At 25°C 50%RH)
Sensor Response Time	About 7 minutes (90%)	
Humidity Hysteresis	–	±1%RH (30 to 90%RH)
Operating Environment	Temperature: 0 to 55°C Humidity: 90%RH or less (no condensation)	
Storage Environment	Temperature: 0 to 55°C Humidity: 90%RH or less (no condensation)	
Conditions for Use	Do not expose to condensation, dampness, corrosive gases or organic solvents	
Sensor Dimensions	H18 × W51.5 × D10 mm	
Cable Length	1.5 m	

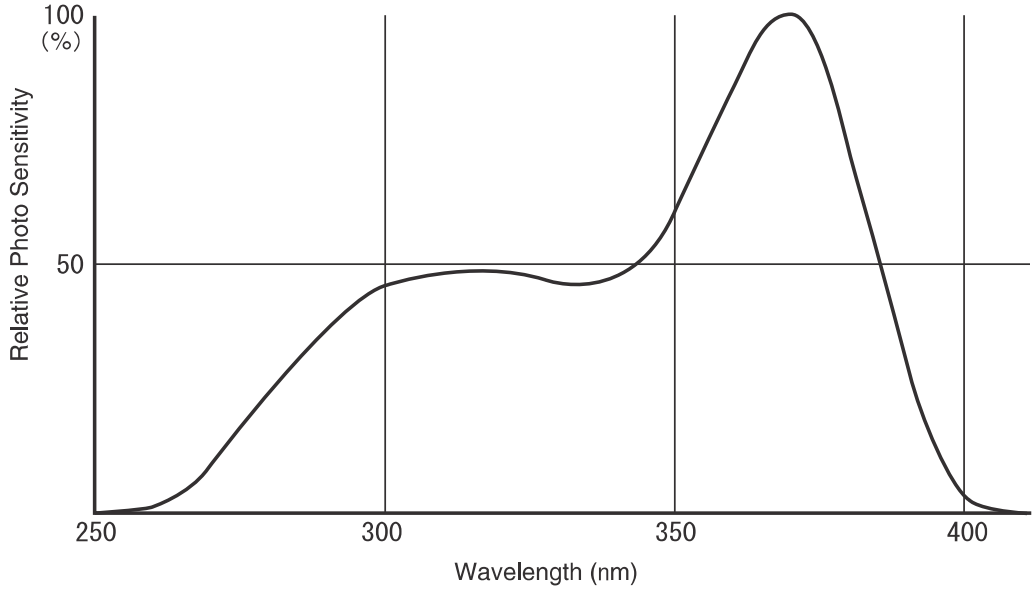
Relative Spectral Response Characteristics Graph (Illuminance)

Broken line: the CIE standard response function V (λ)
Solid line: ISA-3151



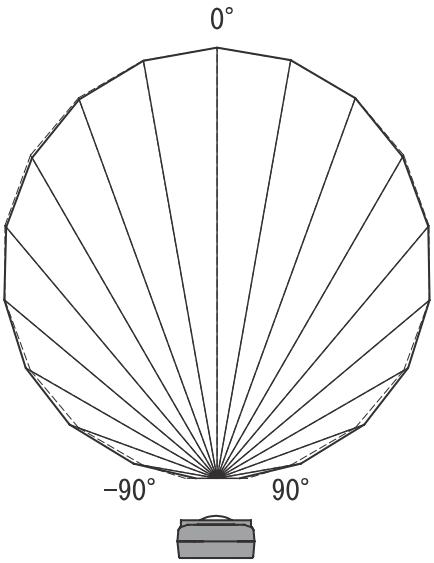
Relative Spectral Response Characteristics Graph (UV)

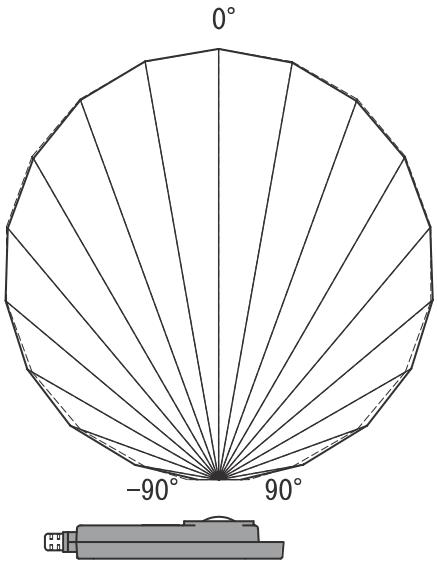
ISA-3151



Cosine Correction Characteristics (Illuminance)

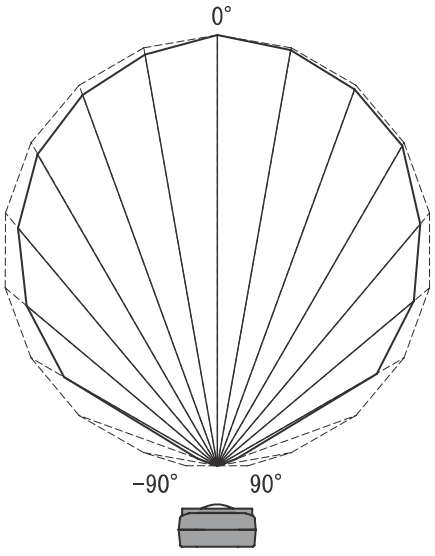
Broken line: cos θ
Solid line: Measurement Value

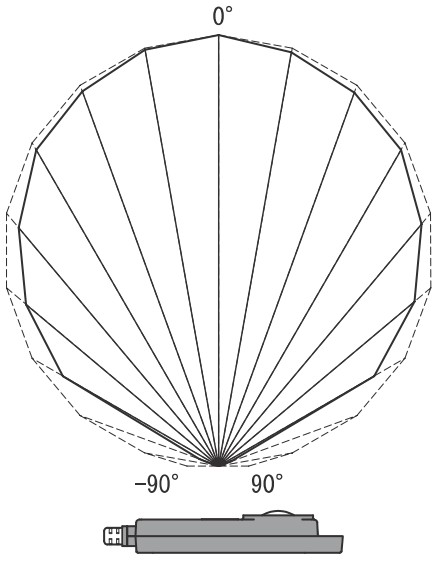




Cosine Correction Characteristics (UV)

Broken line: cos θ
Solid line: Measurement Values





"Illuminance UV Recorder for Windows" Operating Environment

Compatible OS	Microsoft Windows 7 32/64bit English Microsoft Windows Vista 32bit English Microsoft Windows XP 32bit (SP2 or above) English
Memory Capacity	Enough memory to stably operate Windows
Disc Capacity	More than 20 MB free space (More free space is necessary for data)
Monitor	SVGA (800 × 600) more than 256 colors

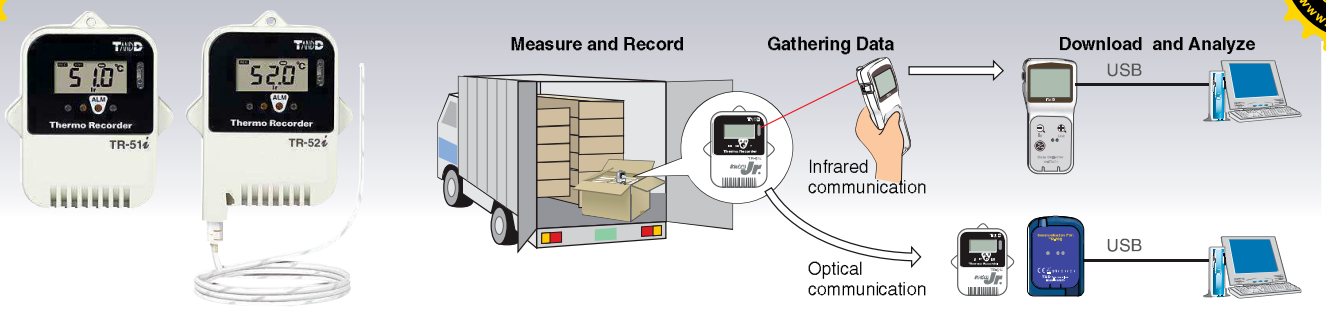
Compact Temperature Data Logging System

TR-5*i* Series

Infrared Interface
Easy-to-Read Display
Durable Waterproof Loggers

T&D Corporation

CE



Place Anywhere Compact Waterproof Type

The compact size allows it to be placed almost anywhere. Also, its durable body with waterproof and dustproof capacity makes it possible to be used in harsh environments.

TR-51i :

The TR-51i with an internal temperature sensor offers superior waterproof capacity and moderate response time; it is suitable for use in transportation and storage, as well as, in harsh environments.

TR-52i :

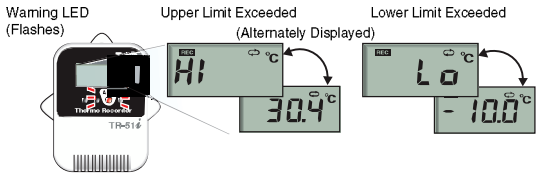
The TR-52i with an external temperature sensor is highly versatile and ideal for use in situations where a quicker response (compared to TR-51i) is required.

Wide Measurement Range: -60 to155°C

The TR-51i can measure and record temperature from -40°C to 80°C and the TR-52i can measure and record in the even wider range of -60°C to 155°C.

Warning Monitoring Function

Using the dedicated software "T&D Recorder for Windows (TR-5, 7xU)", you can make Upper / Lower Limits and Judgment Time settings for the TR-51i/52i. If a measurement exceeds one of the set limits, the warning LED and message will be displayed. Because the warning LED and message will remain ON until the data is downloaded, there is no way to miss any important warnings.



Storage Capacity of 16,000 Readings

One Data Logger can store up to 16,000 readings. At a recording interval of 10 minutes that would equal about 111 days, and at an interval of 60 minutes that would equal about 22 months of non-stop consecutive recording.

Note: * The dedicated software "T&D Recorder for Windows" provides 15 recording interval choices (from 1 second to 60 minutes) to meet your needs.

Low Energy Consumption Design

The low energy consumption design of the TR-5i series provides continuous operation for up to 4 years. When the battery needs to be replaced, the battery replacement mark will appear.

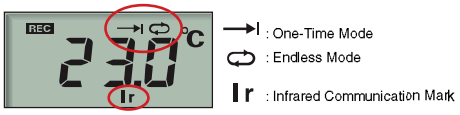
Estimated Battery Life:
When a new battery is being used and data downloading occurs four times a month (with infrared communication switched OFF)

Recording Interval	1 Second	2 seconds	5 seconds	10 seconds or longer
Battery Life	About 18 months	About 2 years	About 3 years	About 4 years

Note: * The battery replacement mark will appear based upon the calculation of battery use. It may appear sooner than noted above.
* Battery life varies depending upon frequency of communication, infrared communication settings, blinking of the warning LED, and measuring environments such as the ambient temperature.

Recording Settings Display

Recording mode (One-Time or Endless) and Infrared Communication settings will be displayed in the LCD.



(The Infrared communication status is shown here)

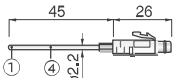
Possible Temperature Measurement Range: - 60 to 155°C / Sensor Temperature Resistance: -70 to 180°C
Temp Measurement Accuracy: Average +/-0.3°C (-20 to 80°C) Average +/-0.5°C (-40 to -20°C / 80 to 110°C) Average +/-1.0°C (-60 to -40°C / 110 to 155°C)
① Thermistor ② Stainless pipe (SUS316) ③ Fluoropolymer Compaction Tube ④ Fluoropolymer Coated Electrical Wire ⑤ Fluoropolymer Coated Mold

Fluoropolymer Coated Sensor

[Unit : mm]

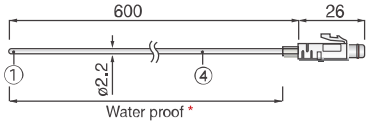
TR-5101

Cable Length: 45mm (1.8in)
Thermal Time Constant:
Approx. 30 Sec. (in air)
Approx. 4 Sec. (in agitated water)



TR-5106

Cable Length: 0.6m (24in)
Thermal Time Constant:
Approx. 30 Sec. (in air)
Approx. 4 Sec. (in agitated water)

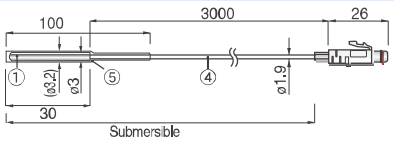


* Water Resistance: The fluoropolymer-coated section is waterproof.

Water Immersible Sensor

TR-5530

Cable Length: 3.0m (120in)
Thermal Time Constant:
Approx. 120 Sec. (in air)
Approx. 6 Sec.
(in agitated water)

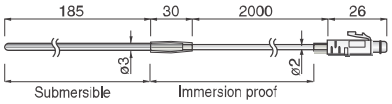


Stainless Protection Sensor

[Unit : mm]

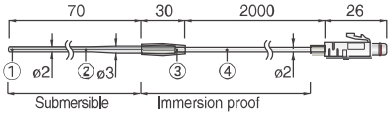
TR-5220

Cable Length: 2.0m (80in)
Thermal Time Constant:
Approx. 36 Sec. (in air)
Approx. 7 Sec. (in agitated water)



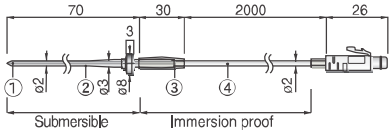
TR-5320

Cable Length: 2.0m (80in)
Thermal Time Constant:
Approx. 12 Sec. (in air)
Approx. 2 Sec. (in agitated water)



TR-5420

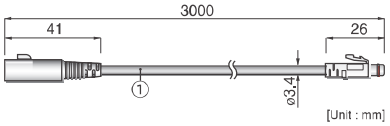
Cable Length: 2.0m (80in)
Thermal Time Constant:
Approx. 12 Sec. (in air)
Approx. 2 Sec. (in agitated water)



TR-2C30 (Only use for Temperature Sensors)

Cable Length: 3.0m (120in)
Splash Resistant (IP64)

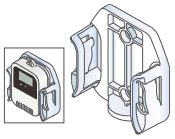
Materials:
① Vinyl Coated Electrical Wire



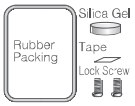
[Unit : mm]

Note: * An error of about +0.3°C occurs at normal temperature while an error of about +0.5°C will occur at around -50°C.

TR-05K3: Wall Attachment

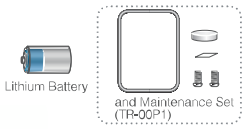


TR-00P1: Maintenance Set



A set of replacement parts for maintaining water resistance.

TR-11P2 : Battery Set

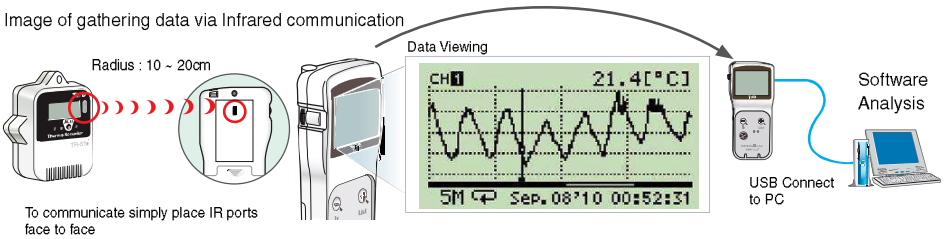


...ese interfaces enable the collecting of recorded data for monitoring on site or saving to a PC.

Easy Data Collection, Easy Graph Display

- Collect Data anywhere, at anytime; No PC necessary
- One Logger at full storage capacity can be downloaded via Infrared communication in 55 seconds or via optical communication in just 24 seconds
- The collected data can be immediately viewed on site and checked for warning occurrences
- The Data Collector can store recorded data from up to 16 loggers at full capacity
- All operations can be carried out with one hand
- Can also collect data from older versions of our Data Loggers

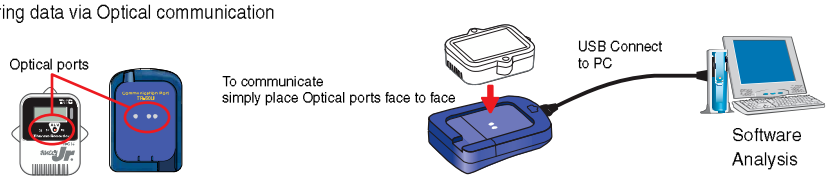
Image of gathering data via Infrared communication



High Speed Data Downloading Data

- Use for downloading data directly to a PC
- Download data from a Logger at full storage capacity in about 20 seconds
- Extremely lightweight at only 30 grams

Image of gathering data via Optical communication

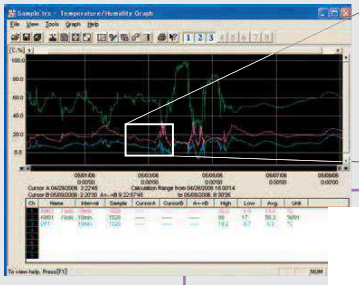


Free-of-Charge Software Included with PC Communication Interfaces

Software Updates and Info Available on Our Website

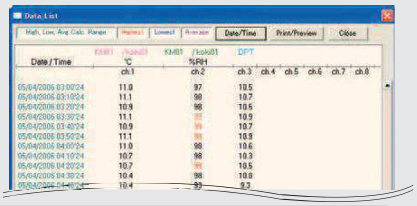
This free of charge software is bundled with the Data Collection Device. Our user-friendly software makes all types of settings a snap: from setting up recording conditions and warning monitoring to carrying out adjustments and other functions. The Graph Tools program intuitive operation allows the User to easily hide or view channels, zoom in and out on data, switch back and forth from °C to °F, and view data in table form.

Temperature / Humidity Graph



Enlarged View

View in Table Form

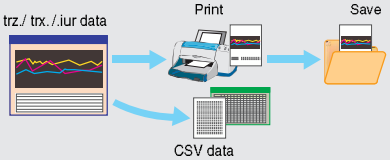


View in Table Form

Graph data can be easily viewed as a data list. The highest and lowest values are shown in easily distinguishable colors.

From Graph Editing to Data Analysis

It is possible to hide, re-order and delete channels, edit recording start times, and make changes to colors used for the graph scale lines, data lines and background. Also you can move the A and B cursor at the bottom of the graph to view data readings for those points and the calculated difference between the points.By saving graph data as CSV Format Text File data, that data can then be uploaded into common spreadsheet software for further data analysis.



Adjustment Settings for the TR-51i / 52i

The software enables you to use the measurement adjustment function to correct for TR-51i and TR-52i measurement inaccuracies.When using multiple measuring devices, this function allows the user to correct for inaccuracies found in measured values when compared to a standard measurement (the value measured by the standard device). Measurements can be adjusted and recorded based on a standard measurement. The software allows for adjustment settings to be made to Remote Unit measurements by simply selecting the adjustment method from either "1 Point Adjustment" or "2 Point Adjustment" and entering the values for "Before Adjustment" and "After Adjustment".

Device Name	TR-51i	TR-52i
Measurement Item	Temperature	Temperature
Number of Channels	1 Ch (Internal Sensor Type)	1 Ch (External Sensor Type)
Measurement Range	- 40 to 80˚C	- 60 to 155˚C
Unit of Measurement	˚C, ˚F	˚C, ˚F
Response Time (in 90% still air)	About 35 minutes	-
Measuring Accuracy	Avg. +/-0.5˚C	Avg.+/-0.3˚C: - 20 to 80˚C Avg.+/-0.5˚C: - 40 to - 20˚C 80 to 110˚C Avg.+/-1.0˚C: - 60 to - 40˚C 110 to 155˚C
Measurement Display Resolution	0.1˚C	
Recording Intervals	Select from 15 choices:1, 2, 5, 10, 15, 20 and 30 seconds / 1, 2, 5, 10, 15, 20, 30 and 60 minutes	
Storage Capacity	Up to 16,000 readings	
Recording Start Method	Immediate Start / Programmed Start	
Recording Modes	Endless / One Time	
LCD Displayed Items	Measured Temperature, Recording Status, Recording Mode Infrared Communication Status Battery Life Warning, Unit of Measurement, Full (Storage Capacity FULL), Unconnected Sensor Measurement Range Exceeded, Upper / Lower Limit Exceeded	
Communication Interfaces	Optical / Infrared Communication	
Infrared Communication	IrPHY 1.2 low power	
Communication Time	When downloading a Unit at full storage capacity: Optical Communication : about 25 seconds (TR-50U) about 150 seconds (other devices) Infrared Communication: about 55 seconds (TR-57DCi)	
Power (*1)	Lithium Battery (LS14250) / Lithium Battery (CR2)	
	About 4 years (2 years if it's been selected to "Permit" infrared communication)	
Waterproof Capacity	Immersion proof	Splash proof
Dimensions	H62 x W47 x D19mm (excluding protrusions and sensor part)	
Weight	About 54g (including battery)	About 55g (including battery / excluding sensor)
Operating Environment	- 40 to 80˚C When using Lithium Batteries (CR2) sold in stores : -20 to 60˚C	
Data Collection Devices	Data Collectors: TR-57DCi Communication Ports: TR-50U	

(*1) The included Lithium Battery (LS14250) is not sold in stores. Please purchase the "Optional Battery Set TR-11P2" for replacement.
(*2) Battery life varies depending upon measuring environment, frequency of communication, Unit settings, and battery performance.

For installation, it is necessary to have Administrator (Computer Administrator) rights.

Software Names	T&D Recorder for Windows (TR-5, 7xU)
Compatible OS	Microsoft® Windows® 7 32bit/64bit English Microsoft® Windows Vista® 32bit English Microsoft Windows® XP 32bit (SP2 or above) English
PC/CPU	A Stable Windows Operating Environment
Memory	A Stable Windows Operating Environment
Hard Disk	More than 30 MB of free space (Data will need more space)
Monitor	SVGA (800 x 600) more than 256 colors

Device Name	TR-57DCi
Compatible Devices	TR-51i / 52i, TR-51S / 52S, TR-51 / 51A / 52, TR-74Ui / 77Ui, TR-71U / 72U / 73U, TR-71S / 72S, TR-71 / 72, VR-71, RTR-501 / 502 / 503 / 574, RTR-51A / 52A / 53A, RVR-52A, RTR-51 / 52 / 52Pt / 53, RVR-52
Storage Capacity	Up to 256,000 readings 16 units of TR-51i at full storage capacity (16,000 readings x 1ch) 16 units of TR-71U at full storage capacity (8,000 readings x 2ch) 10 units of TR-73U at full storage capacity (8,000 readings x 2ch) 7 units of TR-74Ui at full storage capacity (8,000 readings x 4ch) When downloading units at non-full storage capacity, it can store and manage up to 250 downloading sessions.
Functions	Downloading Recorded Data, Viewing Saved Data in Graph Form, Recording Start Settings, Displaying Highest and Lowest Measurement
LCD Displayed Items	Operation Menu, Graph Display, Battery Life Warning Display, Calendar and Clock, Contrast Adjustment, Backlight
Power	AAA Alkaline Battery (LR03) x 2 (AAA Ni-Cd batteries or AAA Ni-MH batteries (1.2V) may also be used.) AC Adaptor (optional)
Battery Life	About 100 days at 1 hour of daily use * Battery life varies depending upon the type of battery, the measuring environment, the frequency of communication, and the ambient temperature in which it is used.
Data Backup	About 1 month (Saved data will be erased if all battery power is lost.)
PC Communication Interfaces	USB Communication, RS-232C Communication 19,200 bps
Data Logger Communication Interfaces	RS-232C Communication: 9,600 to 19,200 bps Optical Communication: 2,400 to 19,200 bps Infrared Communication
Communication Time	- Between PC and TR-57DCi USB Communication (16,000 readings x 1ch): approx. 12 seconds USB Communication (8,000 readings x 4ch): approx. 24 seconds RS-232C Communication (16,000 readings x 1ch): approx. 22 seconds RS-232C Communication (8,000 readings x 4ch): approx. 42 seconds -TR-5i Series Optical Communication (16,000 readings x 1ch): approx. 24 seconds Infrared Communication (16,000 readings x 1ch): approx. 55 seconds -TR-7Ui Series Infrared Communication (8,000 readings x 2ch): approx. 55 seconds Infrared Communication (8,000 readings x 4ch): approx. 77 seconds -TR-5S Series Optical Communication (16,000 readings x 1ch): approx. 24 seconds
Dimensions	H125mm x W58mm x D23.8mm (excluding protrusions)
Weight	About 110g (including two AAA batteries)
Operating Environment	Temperature: 0 to 50˚C Humidity: 90 RH% or less (no condensation
Accessories	US-15C (USB communication cable / USB-A plug<->USB mini-B plug) x 1 TR-6C10 (Serial communication cable / mini-RS<->mini-RS) x 1 AAA Alkaline Battery (LR03) x 2 User's Manual (Warranty) x 1, Software (CD-ROM) x 1

Device Name	TR-50U
Compatible Devices	TR-51i / 52i, TR-51S / 52S, TR-51 / 51A / 52
PC Communication Interfaces	USB Communication: USB 1.1
Communication Time	When downloading units at full storage capacity: TR-51i /52i, TR-51S/52S: About 20 seconds (19200bps) TR-51A / 52 : About 160 seconds (2400bps)
Dimensions	H80mm x W56mm x D16.5mm (excluding protrusions)
Weight	About 30g
Operating Environment	Temperature: -10 to 60 ˚C Humidity: less than 90%RH (No condensation)
Accessories	US-15C (USB communication cable / USB-A plug<->USB mini-B plug) x 1 User's Manual (Warranty) x 1, Software (CD-ROM) x 1

For product Information, software update and FAQ's:
http://www.tandd.com/

Caution regarding safety
For safe operation carefully read instructions before using this unit.

■ Distributor

T&D Corporation
817-1 Shimadachi, Matsumoto, Nagano Japan 390-0852
Please send your inquiries to:
E-mail : sales@tandd.com
Facsimile : (+81) 263-40-3152

2011. 05. 16304710003D

APPENDIX D. PRODUCT INFORMATION

The Enlighted Intelligent Lighting Control System™

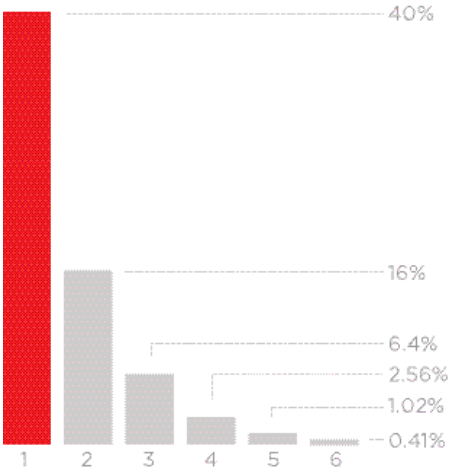
energy savings + ease of installation + occupant comfort

enlighted

Smart. Simple. Savings

The Enlighted Intelligent Lighting Control System is the simplest and most advanced way of managing your building's lighting infrastructure. No other lighting system provides a next generation approach to improving building energy performance. Our Enlighted Smart Sensors™ provide unparalleled savings and the Enlighted Energy Manager™ provides the monitoring and maintenance of the system. Owners of commercial office spaces, warehouses and garages benefit from substantial energy savings while occupants enjoy unprecedented control and comfort.

On the front end, our Enlighted Smart Sensors couple easy and inexpensive installation with unparalleled energy savings.



Percent Occupancy-based Energy Savings at Different Zone Sizes

OCCUPANCY-BASED ENERGY SAVINGS

The true success of an occupancy sensor is measured by its accurate detection. Most traditional occupancy control strategies leave all the lights on in a zone, with even one person present; thus yielding less than 1% in energy savings. Enlighted's approach ensures high energy savings because the lights truly correlate to vacancy and occupancy.

SMART

- Network independent sensors
- Pinpoint control
- Interoperable with all existing lighting types including LED
- Extensible to other energy services and systems

SIMPLE

- Zero lighting design required
- Simple to install—approximately 20 minutes per sensor
- Minimal tenant disruption
- Rapid commissioning

SAVINGS

- 50-70% lighting energy savings
- Cost effective installation
- Low maintenance costs
- Lower cost per unit
- Reduction in carbon footprint

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Monitor + Manage

On the back end, the Enlighted Gateway™ and Enlighted Energy Manager (EEM) provide continuous monitoring and management of your lighting systems. Occupancy, light and temperature data from the sensors is collected and analyzed in real time.

ROI INFORMATION

- The EEM tracks and conveys energy consumption 24/7
- Operators gain precise information on ROI from energy savings

CONFIGURATION AND TUNING

- Profiles in the EEM manage the space according to users' preferences and tasks
- As changes occur, the profiles can be easily updated

INTERFACE TO BUILDING MANAGEMENT SYSTEMS

- The EEM interface enables the system to communicate with a BMS
- Occupancy data from the Enlighted System provides additional savings through interface with HVAC and demand response systems

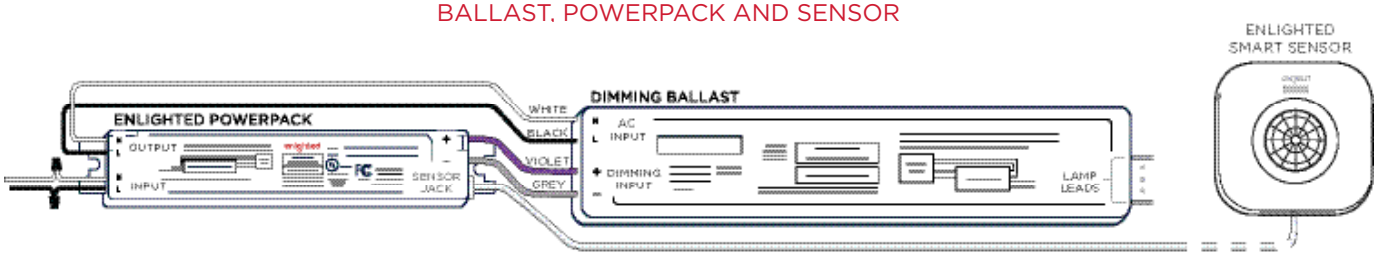
Enlighted Intelligent

The Enlighted Intelligent Lighting Control System comprises three components: the Enlighted Smart Sensor, the Enlighted Gateway and the Enlighted Energy Manager.

THE ENLIGHTED SMART SENSOR powers the Enlighted Intelligent Lighting Control System — the simplest and most advanced lighting control system available today. Enlighted Smart Sensors provide granular control of the building environment without a centralized controller. They yield unprecedented energy savings for building owners while greatly enhancing occupant comfort.

Enlighted Smart Sensors are deployed at every fixture throughout a building, working with all types of lamps –fluorescent, LED and others. They sense occupancy, temperature and ambient light and manage the lights to vary the illumination levels. Because the sensors work autonomously, they are fault tolerant. Each sensor operates irrespective of network outages or other events affecting the overall system. The data collected by each sensor is passed to the Enlighted Energy Manager that tracks and analyzes the energy savings and provides input for other building energy efficiency systems, such as demand response and HVAC.

BALLAST, POWERPACK AND SENSOR



Installing the sensors is a quick and easy process requiring less than 20 minutes per sensor. No specialized skills are required on the part of the installers.

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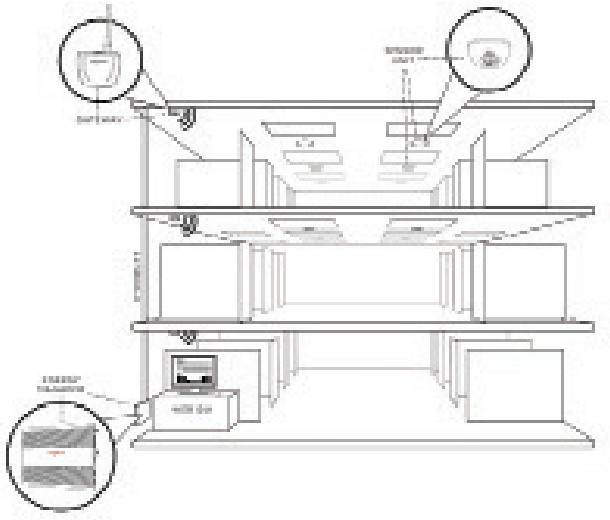
Lighting Control System

THE ENLIGHTED GATEWAY connects Enlighted Smart Sensors and the Enlighted Energy Manager. The Enlighted Gateway communicates with Enlighted Smart Sensors via a wireless network. One or more Enlighted Gateways may be deployed on each floor to relay information between the sensors and the Enlighted Energy Manager appliance. The system architecture enables scaling to very large lighting control applications. The Enlighted Gateway uses industry standard AES encryption to ensure secure connections.

THE ENLIGHTED ENERGY MANAGER is the user interface to the Enlighted Intelligent Lighting Control System. It is a server class appliance that discovers, commissions, and manages Enlighted Smart Sensors. It monitors and reports energy usage. The Enlighted Energy Manager also provides the interface to third party building automation and demand response systems. Industry standard security with encryption safeguard the integrity of the system. Automatic backups prevent data loss and restore fixtures to operational modes.

IMPLEMENTATION OF THE ENLIGHTED SYSTEM



Enlighted Smart Sensors operate autonomously from the network creating a fault tolerant environment. They are linked through a wireless network to the Enlighted Gateways which are connected through ethernet to the Enlighted Energy Manager. Typically, every work space has its own sensor, each floor may have one or several gateways and there is a single energy manager per building.

Quick, Simple Installation

The Enlighted Intelligent Lighting Control System is the easiest and most cost effective lighting control system to install. We use software to do the work that hardware and manual processes perform in conventional systems. There is no design or pre-engineering. Installation technicians do not require special certification. Because no new wiring is involved, the system does not need to be designed around facility constraints.

PER FIXTURE

- 15 MINS — **Powerpack/control unit installation**
- 5 MINS — **Enlighted Smart Sensor installation**
- 1 MIN — **Sensor discovery and commissioning**

PER BUILDING

- 90 MINS — **Enlighted Gateway installation and connection to Enlighted Energy Manager (EEM)**
- 30 MINS — **EEM set up**
- 5 MINS — **EEM profile management**

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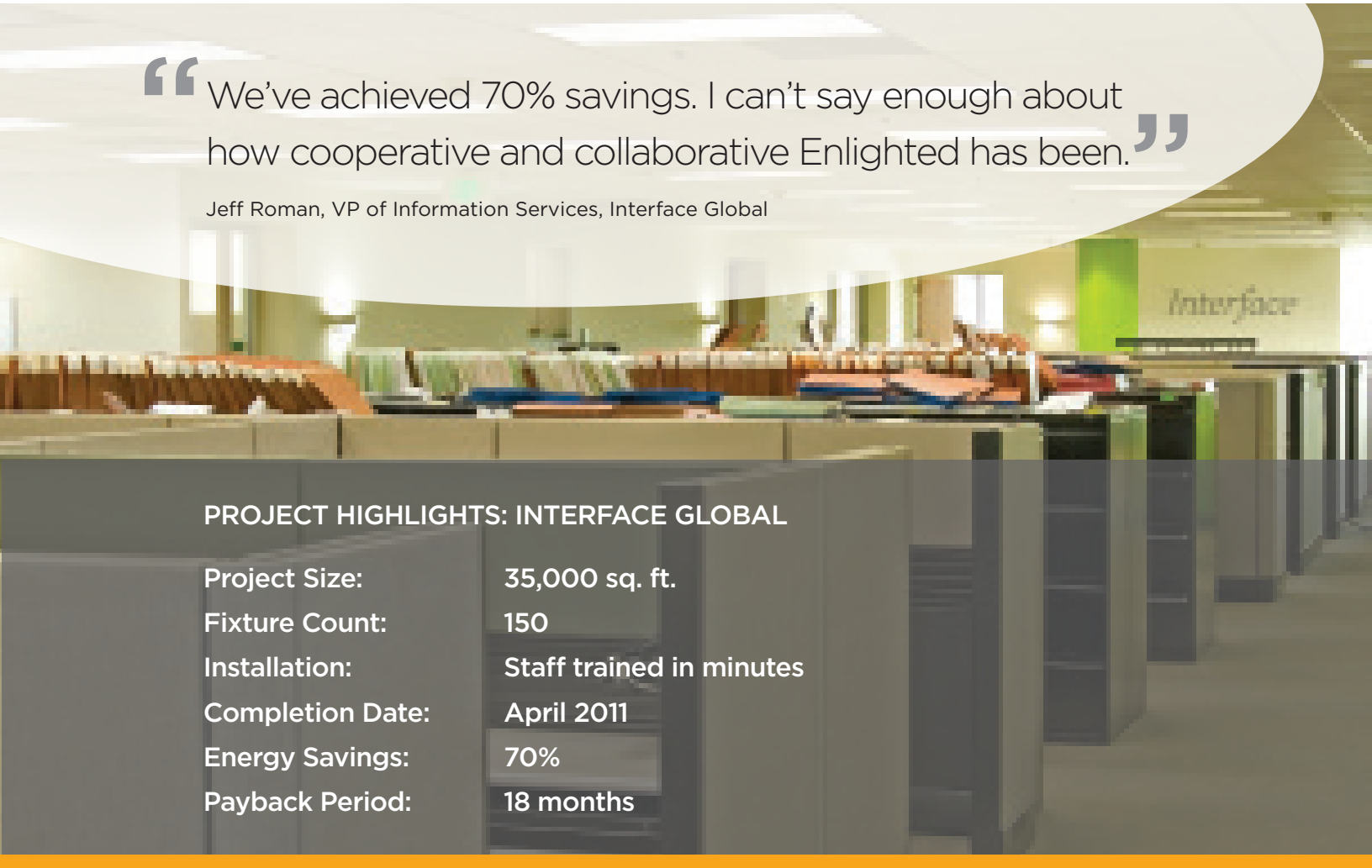
Proven Results

Over 6 million+ square feet installed
50-70% energy savings
35 Fortune 1000 customers

Google, Turner Broadcasting System, LinkedIn,
JDSU, Smart Modular Technologies,
Unico Properties, Tarlton Properties, Interface Global.



"We've achieved 70% savings. I can't say enough about how cooperative and collaborative Enlighted has been."

Jeff Roman, VP of Information Services, Interface Global

PROJECT HIGHLIGHTS: INTERFACE GLOBAL

Project Size:	**35,000 sq. ft.**
Fixture Count:	**150**
Installation:	**Staff trained in minutes**
Completion Date:	**April 2011**
Energy Savings:	**70%**
Payback Period:	**18 months**

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enlighted

enlighted

product spec

Enlighted Smart Sensor™

Fully-integrated, ceiling-mounted devices that connect by wire to light fixtures, forging a system that incorporates all the programmability, sensing and communication capabilities needed to autonomously control illumination levels and collect occupancy and environmental data at the level of personal workspaces.

OVERVIEW

Enlighted Smart Sensors are designed for use with the Enlighted Lighting Control Application. Each sensor is a fully-integrated, microprocessor-based system featuring a sensor array that incorporates motion, dayight and temperature sensing as well as a power meter chip. Connected by wire to the dimmable ballast of each light fixture, Enlighted Smart Sensors provide lighting that saves energy and is responsive to occupant preferences.

While they control light levels over a secure wired connection, the sensors communicate energy, environmental and occupancy data to a central server via a gateway over a standard-protocol wireless network. Enlighted Energy Manager™ software is the user interface to this network, enabling easy definition and management of customizable profiles. These profiles determine lighting behavior, balancing energy savings and occupant comfort. The system enables real-time monitoring and reporting of lighting behavior and energy savings at the room, building, and even campus level. Each appliance running the Enlighted Energy Manager can manage up to 1000 Enlighted Smart Sensors.

FEATURES AND BENEFITS

+ **MICROPROCESSOR CONTROL:** By embedding the control logic in the smart sensor, light levels can be managed with complete autonomy and high reliability. Enlighted Smart Sensor control logic can be remotely upgraded over the wireless network, minimizing disruption.

+ **SOFTWARE DRIVEN**: Enlighted software profiles contain all the instructions needed to adjust lighting level locally according to a multitude of scenarios. Profiles can be edited and exchanged remotely for easy repurposing of space.

+ **DUAL-TECHNOLOGY SENSING**: Occupancy control accuracy is improved by combining input from the smart sensor's passive IR motion sensor and integrated light sensor. The embedded microcontroller can analyze both in real-time to minimize false triggering while accurately reacting to small motion.

+ **FULL REPORTING FUNCTIONS:** The sensor and its control unit report occupancy, power consumption, local light levels and temperatures. With this data the Enlighted System provides complete measurement and verification of savings. The system can also track the condition and operation of each fixture it controls, informing the facility manager of impending failures before they occur.

+ **LIGHTING TECHNOLOGY COMPATIBILITY:** Controls LED, fluorescent, HID, induction or plasma light fixtures.

+ **SIMPLE AND LOW-COST INSTALLATION:** No above-ceiling wiring is necessary. Typical installations follow a one-to-one sensor-per-fixture plan, which makes the installation process simple and fast in its repetitiveness.

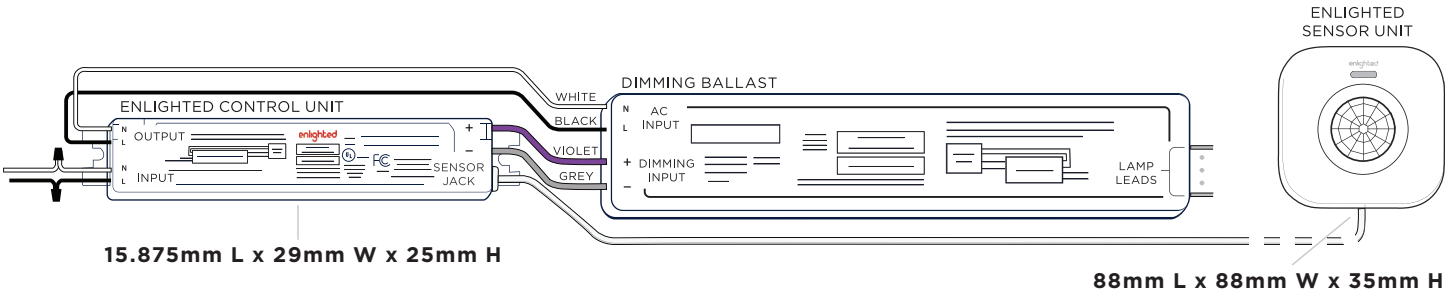
+ **LOCAL METERING**: The control unit contains a power meter chip for measurement and verification of savings.

+ **NO BATTERIES**: Power is supplied by the host fixture.

+ **EXTENSION CAPABILITY:** One smart sensor can control up to four light fixtures, in special cases.

MOUNTING, PHYSICAL DIMENSIONS AND DETECTION AREA

An Enlighted Smart Sensor is comprised of a Sensor Unit and a Control Unit. The Sensor Unit is typically mounted on the ceiling aside the fixture. The Control Unit is mounted within the fixture's enclosure in line with the dimming ballast. The sensing detection area depends upon mounting height. The major motion radius of coverage is approximately 1.25X mounted height. Thus, for the typical 8-foot ceiling, major motion is detected at about a 10 foot radius and minor motion is detected at about 6.5-foot radius. For a 16-foot high-bay ceiling, major motion can be detected at about a 20-foot radius and minor motion at about 12.5 ft. radius. (See *Coverage Pattern Technical Specification* for more detail.)



TECHNICAL SPECIFICATIONS

SENSOR UNIT

Sensing Technology	Dual-Tech Passive IR/Optical
Range	300 ft. Line of Sight
Height Standard Sensor	8 ft - 15 ft.
Height Highbay Sensor	16 ft - 35 ft.
Enclosure	ABS
Input Voltage	10-30V DC
Operating Environment	0-50° C / 32 to 120° F
Radio Frequency	2405-2480 MHz
Wireless Protocol	802.15.4 IEEE
Wireless Range	330 ft. Line of sight
Encryption	AES 128

COMPLIANCE

Worldwide	RoHS
United States	UL Listed, FCC
Canada	IC
Europe	CE Mark
China	CMIIT

CONTROL UNIT

Operating Environment	0-60° C/32 to 120°F
Connector Type	RJ-11 modular plug
Enclosure	30% fiber glass reinforced PET
Input Voltage	120/277 VAC
Input Frequency	50/60 Hz
Dimmer Control Input	Push in style; 16-24 AWG
Dimmer Control Output	0-10V DC; +/-10mA
Lead Wires	24" 300VAC, 18 AWG solid
Max Switched Circuit	400W@120VAC/600W@277VAC
Relays	5 AMPS

COMPLIANCE

Worldwide	RoHS
United States	UL Listed
Canada	UL Canada
Europe	CE Mark
China	CMIIT

ORDERING INFORMATION

☐ **MODEL: SU-2-00**	**Standard Mount Sensor Unit**
☐ **MODEL: SU-2-HB**	**High-bay Mount Sensor Unit**
☐ **MODEL: CU-2-1R**	**Control Unit**

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A Maxim Integrated Products Brand

78M6613
Single-Phase
AC Power Measurement IC

DATA SHEET

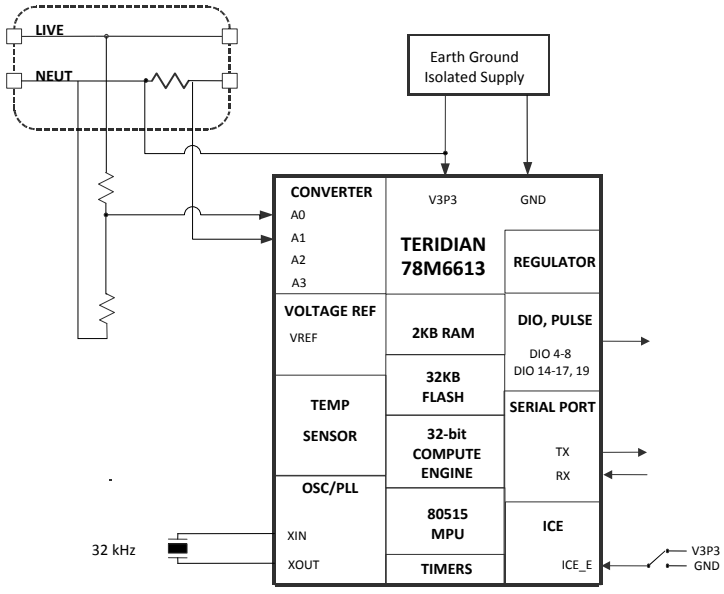
DS_6613_018 **March 2011**

DESCRIPTION

The 78M6613 is a highly integrated IC for simplified implementation of single-phase AC power measurement into power supplies, smart appliances, and ot her applications with embedded AC load monitoring and control. It is packaged in a small, 5mm x 5mm, 32-pin QFN package for optimal space savings.

At the measurement interface, the device provides four analog inputs for interfacing to voltage and current sensors. Voltages from the sensors are fed to our Single Converter Technology® that uses a 22-bit delta-sigma ADC, independent 32-bit compute engine (CE), digital temperature compensation, and precision voltage references to provide better than 0.5% power measurement accuracy over a wide 2000:1 dynamic range.

The integrated MPU core and 32 KB of flash memory provides a flexible means of configuration, post-processing, data formatting, and interfacing to any host processor through the UART interface and/or DIO pins. Complete application firmware is available and can be preloaded into the IC during manufacturing test. Alternatively, a complete array of ICE, development tools, and programming libraries are available to allow customization for each application.



Single Converter Technology is a registered trademark of Maxim Integrated Products, Inc.

FEATURES

- < 0.5% Wh Accuracy Over Wide 2000:1 Current Range and Over Temperature
- Voltage Reference < 40ppm/°C
- Four Sensor Inputs—V3P3A Referenced
- 22-Bit Delta-Sigma ADC with Independent 32-Bit Compute Engine (CE)
- 8-Bit MPU (80515), One Clock Cycle per Instruction with 2KB MPU XRAM
- 32KB Flash with Security
- Integrated In-Circuit Emulator (ICE) Interface for MPU Debug
- 32kHz Time Base with Hardware Watchdog Timer
- UART Interface and Up to 10 General-Purpose 5V Tolerant I/O Pins
- Packaged in a RoHS-Compliant (6/6) Lead(Pb)-Free, 32-Pin QFN (5mm x 5mm)
- Complete Application Firmware Provides:
  - True RMS Calculations for Current, Voltage, Line Frequency, Real Power, Reactive Power, Apparent Power, and Power Factor
  - Accumulated Watt-Hours, Kilowatt-Hours
  - Intelligent Switch Control at Zero Crossings
  - Digital Temperature Compensation
  - Phase Compensation (±15°)
  - Quick Calibration Routines
  - 46–64Hz Line Frequency Range with Same Calibration

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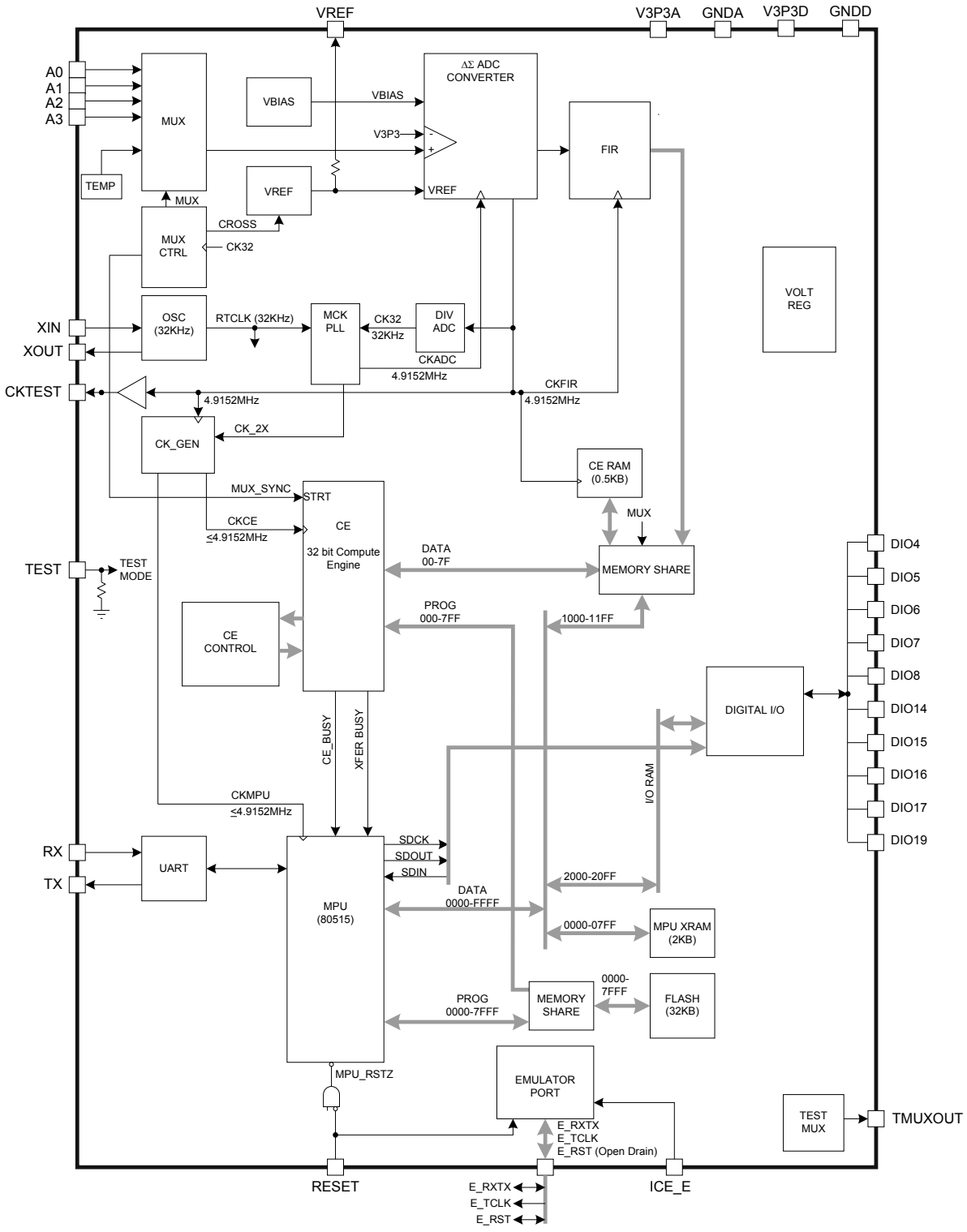


Figure 1: IC Functional Block Diagram

1 Hardware Description

1.1 Hardware Overview

The Teridian 78M6613 single-chip measurement unit integrates all primary functional blocks required to embed solid-state AC power and energy measurement. Included on chip are:

- An analog front end (AFE)
- An independent digital computation engine (CE)
- An 8051-compatible microprocessor (MPU) which executes one instruction per clock cycle (80515)
- A voltage reference
- A temperature sensor
- RAM and Flash memory
- A variety of I/O pins

Current sensor technologies supported include Current Transformers (CT) and Resistive Shunts.

In a typical application, the 32-bit compute engine (CE) of the 78M6613 sequentially processes the samples from the voltage inputs on pins A0, A1, A2, A3 and performs calculations to measure active energy (Wh), reactive energy (VARh), A^2h, and V^2h for four-quadrant measurement. These measurements are then accessed by the MPU, processed further and output using the peripheral interfaces available to the MPU.

In addition to the temperature-trimmed ultra-precision voltage reference, the on-chip digital temperature compensation mechanism includes a temperature sensor and associated controls for correction of unwanted temperature effects on measurement. Temperature dependent external components such as crystal oscillator, current transformers (CTs), and their corresponding signal conditioning circuits can be characterized and their correction factors can be programmed to produce measurements with exceptional accuracy over the industrial temperature range, if desired.

A block diagram of the IC is shown in Figure 1. A detailed description of various functional blocks follows.

1.2 Analog Front End (AFE)

The AFE of the 78M6613 is comprised of an input multiplexer, a delta-sigma A/D converter and a voltage reference.

1.2.1 Input Multiplexer

The input multiplexer supports up to four input signals that are applied to pins A0, A1, A2 and A3 of the device. Additionally, using the alternate mux selection, it has the ability to select the on-chip temperature sensor. The multiplexer can be operated in two modes:

- During a normal multiplexer cycle, the signals from the A0, A2, A1, and A3 pins are selected.
- During the alternate multiplexer cycle, the temperature signal (TEMP) is selected, along with the signal sources shown in Table 1.

The alternate mux cycles are usually performed infrequently (e.g. every second) by the MPU. Table 1 details the regular and alternative MUX sequences. Missing samples due to an ALT multiplexer sequence are filled in by the CE.

Table 1: Inputs Selected in Regular and Alternate Multiplexer Cycles

Regular MUX Sequence				ALT MUX Sequence			
Mux State				Mux State			
0	1	2	3	0	1	2	3
A0	A1	A2	A3	TEMP	A1	V3P3D	A3

In a typical application, A1 and A3 are connected to current sensors that sense the current on each branch of the line voltage. A0 and A2 are typically connected to voltage sensors through resistor dividers. The multiplexer control circuit is clocked by CK32, the 32.768 kHz clock from the PLL block, and launches with each new pass of the CE program.

1.2.2 A/D Converter (ADC)

A single delta-sigma A/D converter digitizes the voltage and current inputs to the 78M6613. The resolution of the ADC is 22 bits. Conversion time is two cycles of the CK32 clock.

Initiation of each ADC conversion is controlled by the multiplexer control circuit as described previously. At the end of each ADC conversion, the FIR filter output data is stored into the CE DRAM location.

1.2.3 FIR Filter

The finite impulse response filter is an integral part of the ADC and it is optimized for use with the multiplexer. The purpose of the FIR filter is to decimate the ADC output to the desired resolution. At the end of each ADC conversion, the output data is stored into the fixed CE DRAM location determined by the multiplexer selection.

1.2.4 Voltage References

The device includes an on-chip precision bandgap voltage reference that incorporates auto-zero techniques. The reference is trimmed to minimize errors caused by component mismatch and drift. The result is a voltage output with a predictable temperature coefficient.

1.2.5 Temperature Sensor

The 78M6613 includes an on-chip temperature sensor implemented as a bandgap reference. It is used to determine the die temperature. The MPU reads the temperature sensor output during alternate multiplexer cycles. The primary use of the temperature data is to determine the magnitude of compensation required to offset the thermal drift in the system (see Section 3.3 Temperature Compensation).

1.2.6 Functional Description

The AFE functions as a data acquisition system, controlled by the MPU. The input signals (A0, A1, A2, and A3) are sampled and the ADC counts obtained are stored in CE DRAM where they can be accessed by the CE and, if necessary, by the MPU. Alternate multiplexer cycles are initiated less frequently by the MPU to gather access to the slow temperature signal.

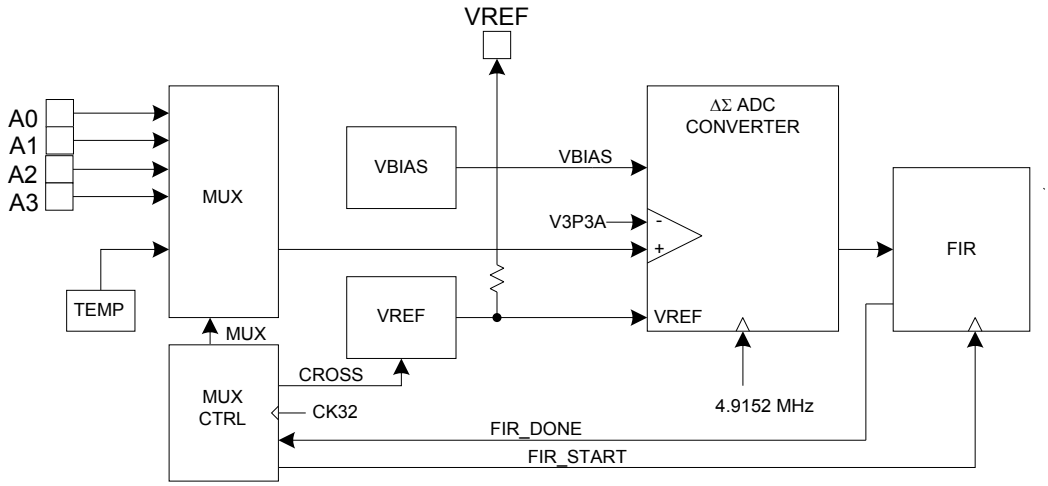


Figure 2: AFE Block Diagram

1.3 Digital Computation Engine (CE)

The CE, a dedicated 32-bit signal processor, performs the precision computations necessary to accurately measure energy. The CE calculations and processes include:

- Multiplication of each current sample with its associated voltage sample to obtain the energy per sample (when multiplied with the constant sample time).
- Frequency-insensitive delay cancellation on all channels (to compensate for the delay between samples caused by the multiplexing scheme).
- 90° phase shifter (for narrowband VARh calculations).
- Monitoring of the input signal frequency (for frequency and phase information).
- Monitoring of the input signal amplitude (for sag detection).
- Scaling of the processed samples based on calibration coefficients.

CE code is provided by Teridian as a part of the application firmware available. The CE is not programmable by the user. Measurement algorithms in the CE code can be customized by Teridian upon request.

The CE program resides in Flash memory. Common access to Flash memory by CE and MPU is controlled by a memory share circuit. Allocated Flash space for the CE program cannot exceed 1024 words (2KB).

The CE DRAM can be accessed by the CE and the MPU. Holding registers are used to convert 8-bit wide MPU data to/from 32-bit wide CE DRAM data, and wait states are inserted as needed, depending on the frequency of CKMPU. The CE DRAM contains 128 32-bit words. The MPU can read and write the CE DRAM as the primary means of data communication between the two processors. CE hardware issues an interrupt when accumulation is complete.

1.4 80515 MPU Core

The 78M6613 includes an 80515 MPU (8-bit, 8051-compatible) that processes most instructions in one clock cycle. Using a 5 MHz (4.9152 MHz) clock results in a processing throughput of 5 MIPS. The 80515 architecture eliminates redundant bus states and implements parallel execution of fetch and execution phases. Normally a machine cycle is aligned with a memory fetch, therefore, most of the 1-byte instructions are performed in a single cycle. This leads to an 8x performance (in average) improvement (in terms of MIPS) over the Intel 8051 device running at the same clock frequency. Actual processor clocking speed can be adjusted to the total processing demand of the application (measurement calculations, memory management and I/O management).

Typical power and energy measurement functions based on the results provided by the internal 32-bit compute engine (CE) are available for the MPU as part of Teridian's standard library. MPU Memory Organization, Special Function Registers, Interrupts, Counters, and other controls are described in the applicable firmware documentation.

1.4.1 UART

The 78M6613 includes a UART that can be programmed to communicate with a variety of external devices. The UART is a dedicated 2-wire serial interface, which can communicate with an external device at up to 38,400 bits/s. All UART transfers are programmable for parity enable, parity, 2 stop bits/1 stop bit and XON/XOFF options for variable communication baud rates from 300 to 38,400 bps.

1.4.2 Timers and Counters

The 80515 has two 16-bit timer/counter registers: Timer 0 and Timer 1. These registers can be configured for counter or timer operations.

In timer mode, the register is incremented every machine cycle, meaning that it counts up after every 12 periods of the MPU clock signal.

In counter mode, the register is incremented when the falling edge is observed at the corresponding input signal T0 or T1 (T0 and T1 are the timer gating inputs derived from certain DIO pins, see the DIO Ports section). Since it takes 2 machine cycles to recognize a 1-to-0 event, the maximum input count rate is 1/2 of the oscillator frequency. There are no restrictions on the duty cycle, however to ensure proper recognition of 0 or 1 state, an input should be stable for at least 1 machine cycle.

1.5 On-Chip Resources

1.5.1 Oscillator

The 78M6613 oscillator drives a standard 32.768 kHz watch crystal. These crystals are accurate and do not require a high-current oscillator circuit. The 78M6613 oscillator has been designed specifically to handle these crystals and is compatible with their high impedance and limited power handling capability.

1.5.2 PLL and Internal Clocks

Timing for the device is derived from the 32.768 kHz oscillator output. On-chip timing functions include the MPU master clock and the delta-sigma sample clock. In addition, the MPU has two general counter/timers.

The ADC master clock, CKADC, is generated by an on-chip PLL. It multiplies the oscillator output frequency (CK32) by 150.

The CE clock frequency is always CK32 * 150, or 4.9152 MHz, where CK32 is the 32 kHz clock. The MPU clock frequency is scalable from 4.9152 MHz down to 38.4 kHz. The circuit can also generate a 2x MPU clock for use by the emulator.

1.5.3 Temperature Sensor

The device includes an on-chip temperature sensor for determining the temperature of the bandgap reference. The primary use of the temperature data is to determine the magnitude of compensation required to offset the thermal drift in the system (see Section 3.3 Temperature Compensation).

1.5.4 Flash Memory

The 78M6613 includes 32 KB of on-chip Flash memory. The Flash memory primarily contains MPU and CE program code. It also contains images of the CE DRAM, MPU RAM, and I/O RAM. On power-up, before enabling the CE, the MPU copies these images to their respective locations. Allocated Flash space for the CE program cannot exceed 1024 words (2 KB).

MPU RAM: The 78M6613 includes 2KB of static RAM memory on-chip (XRAM) plus 256B of internal RAM in the MPU core. The 2KB of static RAM are used for data storage during normal MPU operations.

CE DRAM: The CE DRAM is the working data memory of the CE (128 32-bit words). The MPU can read and write the CE DRAM as the primary means of data communication between the two processors.

1.5.5 Digital I/O

The device includes up to 10 pins of general purpose digital I/O. When configured as inputs, these pins are 5V compatible (no current-limiting resistors are needed). On reset or power-up, all DIO pins are inputs until they are configured for the desired direction under MPU control.

When driving LEDs, relay coils etc., the DIO pins should sink the current into ground (as shown in Figure 3, right), not source it from V3P3 (as in Figure 3, left).

If more than one input is connected to the same resource, the resources are combined using a logical OR.

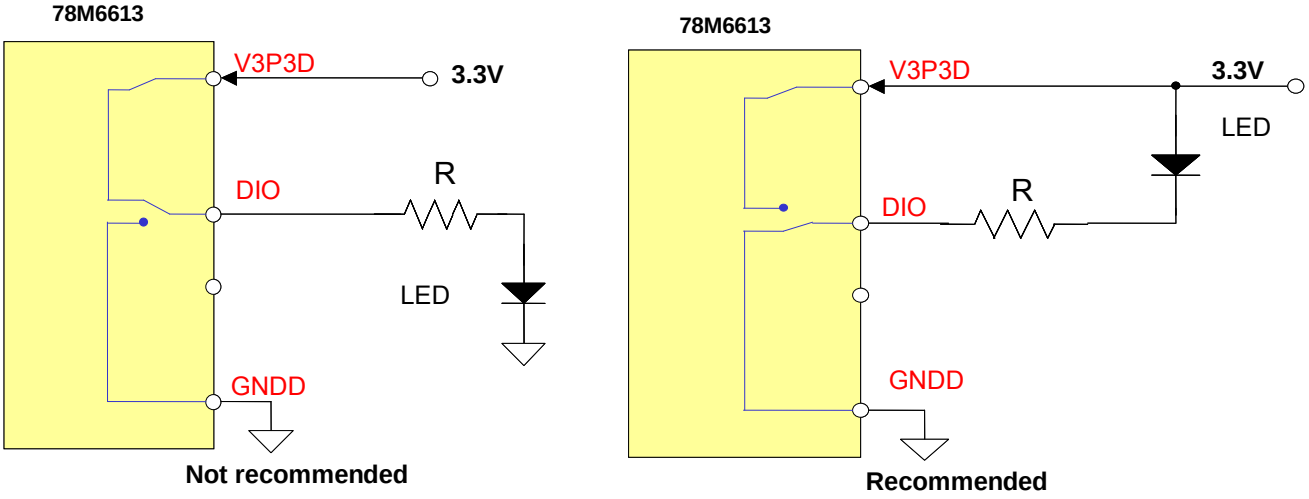


Figure 3: Connecting an External Load to DIO Pins

1.5.6 Hardware Watchdog Timer

In addition to the basic watchdog timer included in the 80515 MPU, an independent, robust, fixed-duration, watchdog timer (WDT) is included in the device. It uses the crystal oscillator as its time base and must be refreshed by the MPU firmware at least every 1.5 seconds. When not refreshed on time the WDT overflows, and the part is reset as if the RESET pin were pulled high, except that the I/O RAM bits will be maintained. 4096 oscillator cycles (or 125 ms) after the WDT overflow, the MPU will be launched from program address 0x0000. Asserting ICE_E will deactivate the WDT.

1.5.7 Program Security

When enabled, the security feature limits the ICE to global Flash erase operations only. All other ICE operations are blocked. This guarantees the security of the user's MPU and CE program code. Security is enabled by MPU code that is executed in a 32 cycle preboot interval before the primary boot sequence begins. Once security is enabled, the only way to disable it is to perform a global erase of the Flash, followed by a chip reset.

1.5.8 Test Ports

TMUXOUT Pin: One out of 16 digital or 8 analog signals can be selected to be output on the TMUXOUT pin. The function of the multiplexer is described in the applicable firmware documentation.

2 Functional Description

2.1 Theory of Operation

The energy delivered by a power source into a load can be expressed as:

$$E = \int_0^t V(t)I(t)dt$$

The following formulae apply for wide band mode (true RMS):

- P = ∑ (i(t) * v(t))
- Q = √(S² – P²)
- S = V * I
- V = √∑v(t)²
- I = √∑i(t)²

For a practical measurement, not only voltage and current amplitudes, but also phase angles and harmonic content may change constantly. Thus, simple RMS measurements are inherently inaccurate, and true RMS measurements must be utilized. A modern solid-state electricity Power and Energy Measurement IC such as the Teridian 78M6613 functions by emulating the integral operation above, i.e. it processes current and voltage samples through an ADC at a constant frequency. As long as the ADC resolution is high enough and the sample frequency is beyond the harmonic range of interest, the current and voltage samples, multiplied with the time period of sampling will yield an accurate quantity for the momentary energy. Summing up the momentary energy quantities over time will result in accumulated energy.

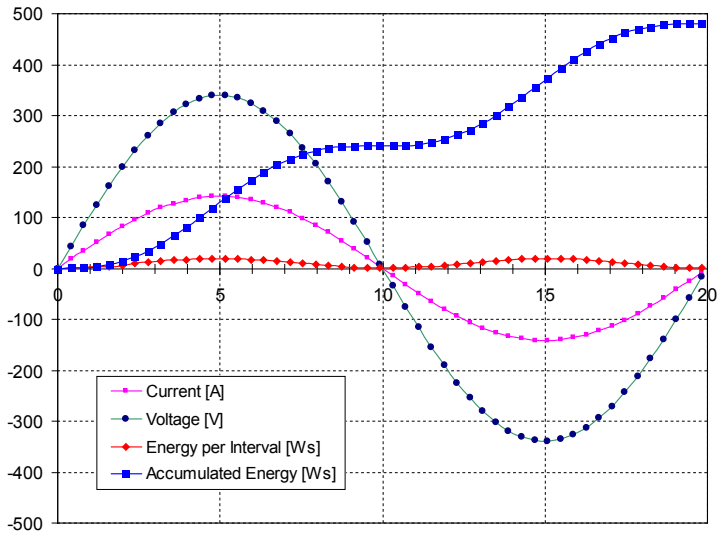


Figure 4: Voltage. Current, Momentary and Accumulated Energy

Figure 4 shows the shapes of V(t), I(t), the momentary power and the accumulated power, resulting from 50 samples of the voltage and current signals over a period of 20 ms. The application of 240 VAC and 100 A results in an accumulation of 480 Ws (= 0.133 Wh) over the 20 ms period, as indicated by the Accumulated Power curve. The described sampling method works reliably, even in the presence of dynamic phase shift and harmonic distortion.

For actual measurement equations, refer to the applicable firmware documentation.

2.2 Reset Behavior

Reset Mode: When the RESET pin is pulled high all digital activity stops. The oscillator continues to run. Additionally, all I/O RAM bits are set to their default states.

Once initiated, the reset mode will persist until the reset timer times out. This will occur in 4096 CK32 clock cycles (32768 Hz clock cycles from PLL block) after RESET goes low, at which time the MPU will begin executing its preboot and boot sequences from address 00.

2.3 Data Flow

The data flow between CE and MPU is shown in Figure 5. In a typical application, the 32-bit compute engine (CE) sequentially processes the samples from the voltage inputs on pins A0, A1, A2, and A3, performing calculations to measure active power (Wh), reactive power (VARh), A^2h, and V^2h for four-quadrant measurements. These measurements are then accessed by the MPU, processed further and output using the peripheral devices available to the MPU.

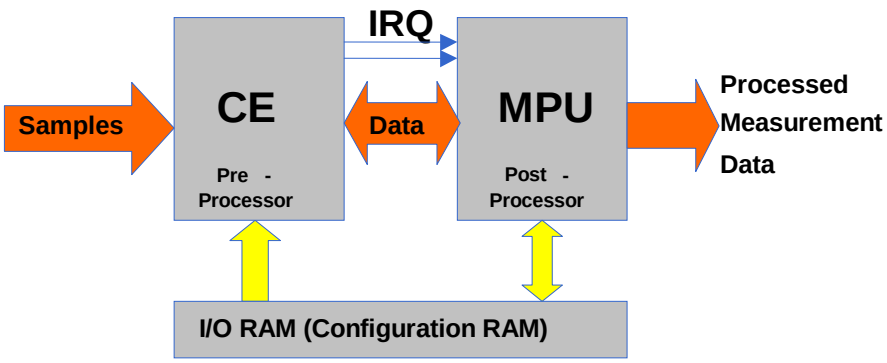


Figure 5: MPU/CE Data Flow

2.4 CE/MPU Communication

Figure 6 shows the functional relationship between CE and MPU. The CE is controlled by the MPU via shared registers in the I/O RAM and by registers in the CE DRAM. The CE outputs two interrupt signals to the MPU to indicate when the CE is actively processing data and when the CE is updating data to the output region of the CE DRAM.

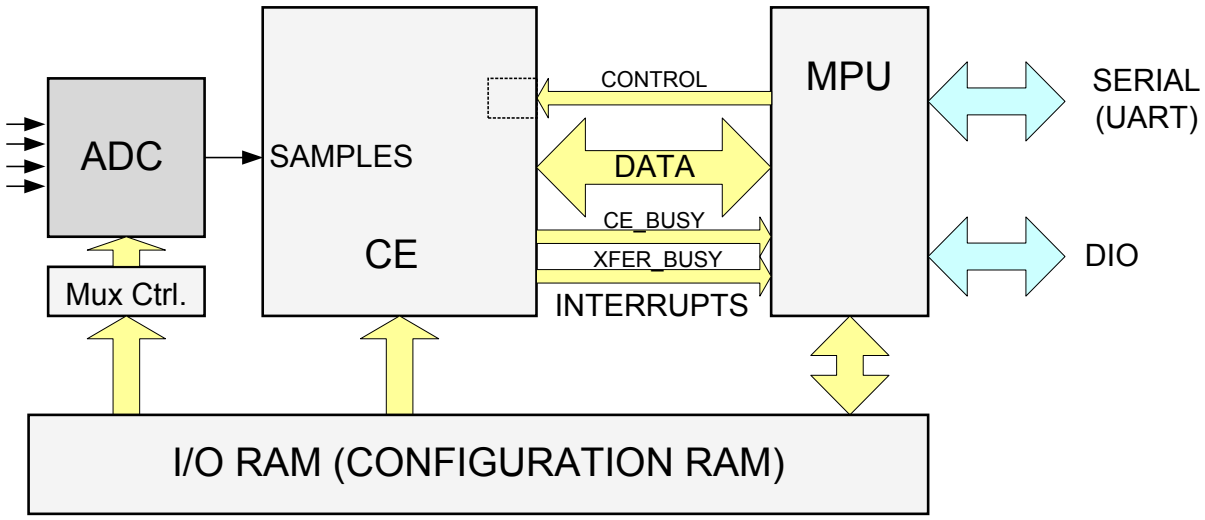


Figure 6: MPU/CE Communication

3 Application Information

3.1 Connection of Sensors (CT, Resistive Shunt)

Figure 7, Figure 8, and Figure 9 show how resistive voltage dividers, resistive current shunts, and current transformers are connected to the voltage and current inputs of the 78M6613.

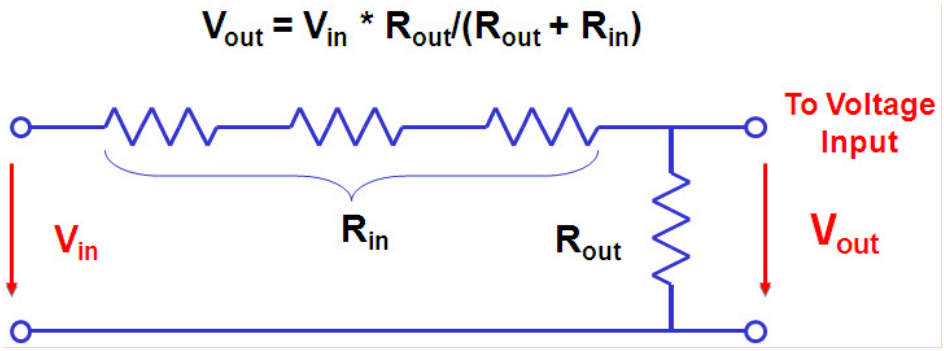


Figure 7: Resistive Voltage Divider

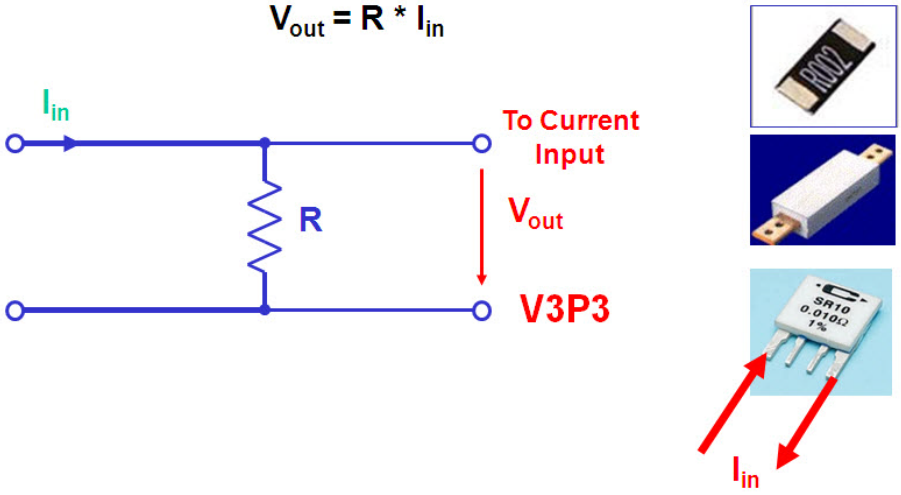


Figure 8: Resistive Current Shunt

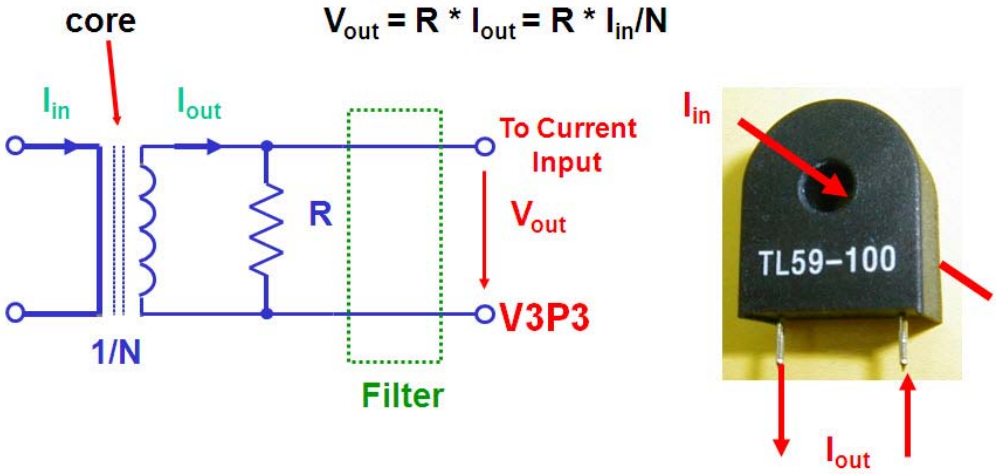


Figure 9: Current Transformer

3.2 Temperature Measurement

Measurement of absolute temperature uses the on-chip temperature sensor while applying the following formula:

$$T = \frac{(N(T) - N_n)}{S_n} + T_n$$

In the above formula, T is the temperature in °C, N(T) is the ADC count at temperature T, N_n is the ADC count at 25°C, S_n is the sensitivity in LSB/°C and T_n is +25°C.

Example: At 25°C a temperature sensor value of 518,203,584 (N_n) is read by the ADC by a 78M6613 in the 32-pin QFN package. At an unknown temperature T the value 449,648,000 is read at (N(T)). The absolute temperature is then determined by dividing both N_n and N(T) by 512 to account for the 9-bit shift of the ADC value and then inserting the results into the above formula, using –2220 for LSB/°C:

$$T = \frac{449{,}648{,}000 - 518{,}203{,}584}{512 \cdot (-2220)} + 25C = 85.3°C$$

3.3 Temperature Compensation

Temperature Coefficients: The internal voltage reference is calibrated during device manufacture.

The temperature coefficients TC1 and TC2 are given as constants that represent typical component behavior (in μV/°C and μV/°C^2, respectively).

Since TC1 and TC2 are given in μV/°C and μV/°C^2, respectively, the value of the VREF voltage (1.195V) has to be taken into account when transitioning to PPM/°C and PPM/°C^2. This means that PPMC = 26.84*TC1/1.195, and PPMC2 = 1374*TC2/1.195).

Temperature Compensation: The CE provides the bandgap temperature to the MPU, which then may digitally compensate the power outputs for the temperature dependence of VREF.

The MPU, not the CE, is entirely in charge of providing temperature compensation. The MPU applies the following formula to determine any gain adjustments. In this formula $TEMP\_X$ is the deviation from nominal or calibration temperature expressed in multiples of 0.1°C:

$$GAIN\_ADJ = 16385 + \frac{TEMP\_X \cdot PPMC}{2^{14}} + \frac{TEMP\_X^2 \cdot PPMC2}{2^{23}}$$

In a power and energy measurement unit, the 78M6613 is not the only component contributing to temperature dependency. A whole range of components (e.g. current transformers, resistor dividers, power sources, filter capacitors) will contribute temperature effects. Since the output of the on-chip temperature sensor is accessible to the MPU, temperature-compensation mechanisms with great flexibility are possible (e.g. system-wide temperature correction over the entire unit rather than local to the chip).

3.4 Connecting 5V Devices

All digital input pins of the 78M6613 are compatible with external 5V devices. I/O pins configured as inputs do not require current-limiting resistors when they are connected to external 5V devices.

3.5 UART (TX/RX)

The RX pin should be pulled down by a 10 kΩ resistor and optionally protected by a 100 pF ceramic capacitor, as shown in Figure 10.

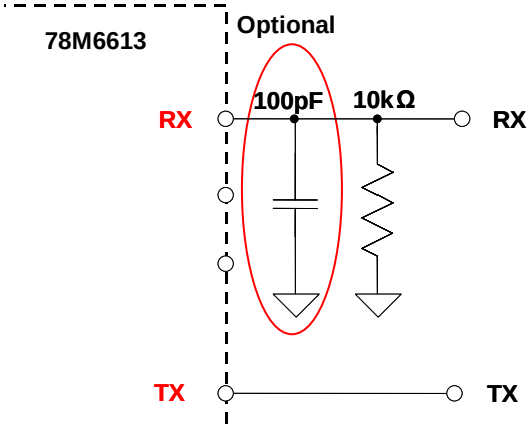


Figure 10: Connections for the RX Pin

3.6 Reset Function and Reset Pin Connections

The 78M6613 requires an external reset circuit to drive the RESET input pin. The reset is used to prevent the 78M6613 from operating at supply voltages outside the recommended operating conditions. Reset ensures the device is set to a known set of initial conditions and that it begins executing instructions from a predetermined starting address.

The reset can be forced by applying a high level to the RESET pin. The reset input is internally filtered (low-pass filter) in order to eliminate spurious reset conditions that can be triggered in a noisy environment. For this reason the RESET pin must be asserted (high) for at least 1µs in order to initiate a reset sequence.

The external reset circuitry should be designed in order to hold the RESET pin high (active) whenever V3P3D is below normal operating level. Refer to Section 4.3, Recommended Operating Conditions. Figure 11 shows the behavior of the external reset circuitry.

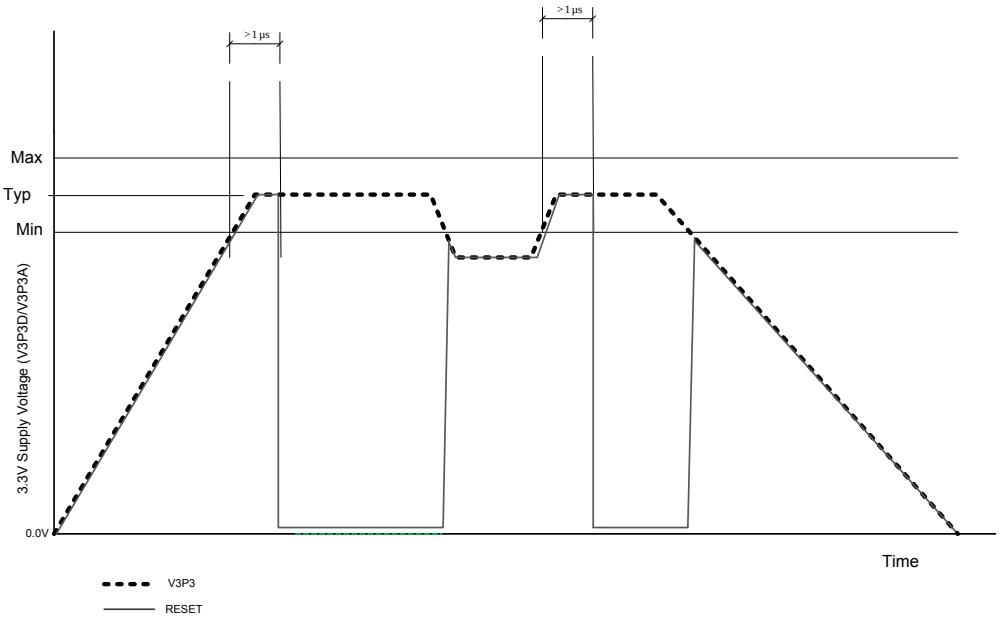


Figure 11: 78M6613 External Reset Behavior

The RESET signal can be generated in a number of different ways. For example, a voltage supervisory device such as Maxim's MAX810S can be used to implement the reset/supply voltage supervisory function as shown in Figure 12.

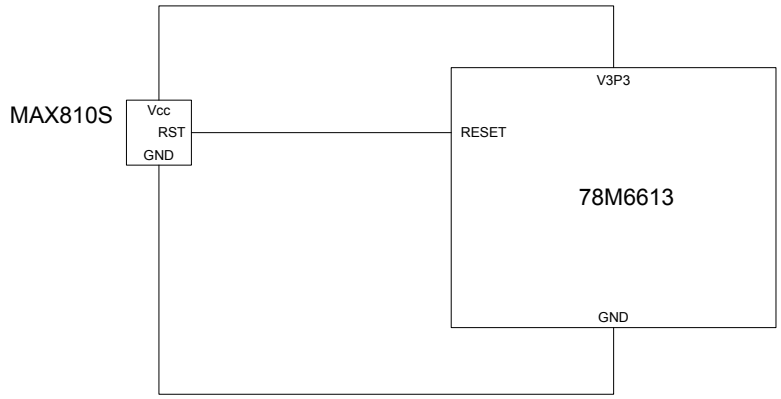


Figure 12: MAX810S Connections to the 78M6613

An alternate solution using discrete components can be used. Figure 13 shows an implementation using a shunt regulator and two transistors.

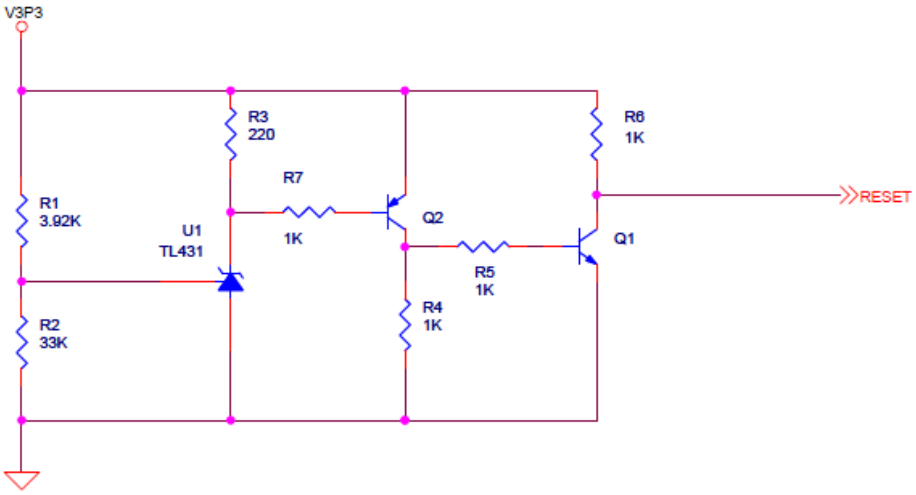


Figure 13: Reset Generator Based On TL431 Shunt Regulator

As long as V3P3 is below the 2.79V threshold set by the voltage divider of R1 and R2, U1 will not conduct current, the base of Q2 will be at the same potential as its emitter, so Q1 will be turned off. With no current flowing in the collector of Q2, the base of Q1 will be low, Q1 will be turned off, and RESET will track V3P3. When the V3P3 rises above 2.79V, the TL431 starts to conduct, the base of Q2 is be pulled low, turning on Q2. This drives the base of Q1 high, turning Q1 on and pulling RESET low. The inherent turn-on and turn-off delays of the TL4313 provide the ~1µs delay required to ensure proper resetting of the 78M6613.

3.7 Connecting the Emulator Port Pins

It is important to bring out the ICE_E pin to the programming interface in order to create a way for reprogramming parts that have the Flash *SECURE* bit (SFR 0xB2[6]) set. Providing access to ICE_E ensures that the part can be reset between erase and program cycles, which will enable programming devices to reprogram the part. The reset required is implemented with a watchdog timer reset (i.e. the hardware WDT must be enabled).

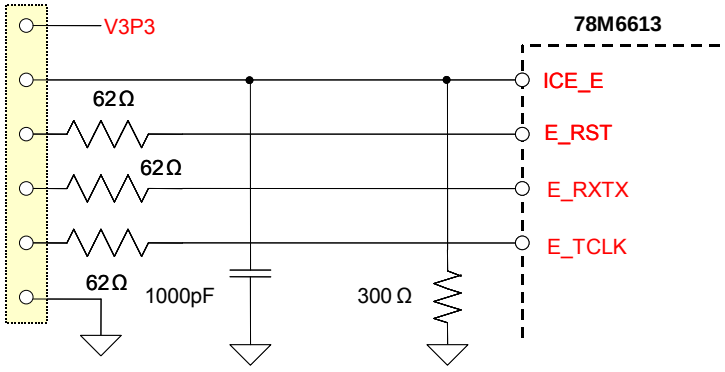


Figure 14: External Components for the Emulator Interface

3.8 Crystal Oscillator

The oscillator of the 78M6613 drives a standard 32.768 kHz watch crystal. The oscillator has been designed specifically to handle these crystals and is compatible with their high impedance and limited power handling capability. Good layouts will have XIN and XOUT shielded from each other.

Since the oscillator is self-biasing, an external resistor must not be connected across the crystal.

3.9 Flash Programming

Operational or test code can be programmed into the Flash memory using either an in-circuit emulator or the Flash Programmer Module (TFP-2) available from Teridian. The Flash programming procedure uses the E_RST, E_RXTX, and E_TCLK pins.

3.10 MPU Firmware Library

Any application-specific MPU functions mentioned above are available from Teridian as a standard ANSI C library and as ANSI "C" source code. The code is pre-programmed in Demonstration and Evaluation Kits for the 78M6613 IC and can be pre-programmed into engineering IC samples for system evaluation. The application code allows for quick and efficient evaluation of the IC without having to write firmware or having to purchase an in-circuit emulator (ICE). A Software Licensing Agreement (SLA) can be signed to receive either the source Flash HEX file for use in a production environment or (partial) source code and SDK documentation for modification.

3.11 Measurement Calibration

Once the 78M6613 Power and Energy Measurement device has been installed in a measurement system, it is typically calibrated for tolerances of the current sensors, voltage dividers and signal conditioning components. The device can be calibrated using a single gain and a single phase adjustment factors accessible to the CE. The gain adjustment is used to compensate for tolerances of components used for signal conditioning, especially the resistive components. Phase adjustment is provided to compensate for phase shifts introduced by certain types of current sensors.

Due to the flexibility of the MPU firmware, any calibration method, such as calibration based on energy, or current and voltage can be implemented. It is also possible to implement segment-wise calibration (depending on current range). Teridian software supports a "quick cal" method.

4 Electrical Specifications

4.1 Absolute Maximum Ratings

Supplies and Ground Pins:	
V3P3	-0.5 V to 4.6 V
GNDD, GNDA	-0.5 V to +0.5 V
Analog Output Pins:	
VREF	-10 mA to +10 mA, -0.5 V to V3P3+0.5 V
Analog Input Pins:	
A0, A1, A2, A3	-10 mA to +10 mA -0.5 V to V3P3+0.5 V
XIN, XOUT	-10 mA to +10 mA -0.5 V to 3.0 V
All Other Pins:	
Configured as Digital Inputs	-10 mA to +10 mA, -0.5 to 6 V
Configured as Digital Outputs	-15 mA to +15 mA, -0.5 V to V3P3D+0.5 V
All other pins	-0.5 V to V3P3D+0.5 V
Operating junction temperature (peak, 100 ms)	140 °C
Operating junction temperature (continuous)	125 °C
Storage temperature	-45 °C to +165 °C
Solder temperature – 10 second duration	250 °C
ESD stress on all pins	4 kV

Stresses beyond Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability. All voltages are with respect to GND.

4.2 Recommended External Components

Name	From	To	Function	Value	Unit
C1	V3P3A	GNDA	Bypass capacitor for 3.3V supply.	≥0.1±10%	µF
CSYS	V3P3D	GNDD	Bypass capacitor for V3P3D.	≥0.1±10%	µF
XTAL	XIN	XOUT	32.768 kHz crystal – electrically similar to ECS .327-12.5-17X or Vishay XT26T, load capacitance 12.5 pF.	32.768	kHz
CXS †	XIN	GND	Load capacitor for crystal (exact value depends on crystal specifications and parasitic capacitance of board).	27±10%	pF
CXL †	XOUT	GND		27±10%	pF

† Depending on trace capacitance, higher or lower values for CXS and CXL must be used. Capacitance from XIN to GND and XOUT to GND (combining pin, trace and crystal capacitance) should be 35 pF to 37 pF.

4.3 Recommended Operating Conditions

Parameter	Condition	Min	Typ	Max	Unit
3.3V Supply Voltage (V3P3)	Normal Operation	3.0	3.3	3.6	V
Operating Temperature		-40		+85	ºC

4.4 Performance Specifications

4.4.1 Input Logic Levels

Parameter	Condition	Min	Typ	Max	Unit
Digital high-level input voltage, V_{IH}		2			V
Digital low-level input voltage, V_{IL}				0.8	V
Input pull-up current, I_{IL} E_RXTX, E_RST, CKTEST Other digital inputs	VIN=0V, ICE_E=1	 10 10 -1	 0	 100 100 1	 µA µA µA
Input pull down current, I_{IH} ICE_E Other digital inputs	VIN=V3P3	 10 -1	 0	 100 1	 µA µA

4.4.2 Output Logic Levels

Parameter	Condition	Min	Typ	Max	Unit
Digital high-level output voltage V_{OH}	I_{LOAD} = 1 mA	V3P3 –0.4			V
	I_{LOAD} = 15 mA	V3P3-0.6[1]			V
Digital low-level output voltage V_{OL}	I_{LOAD} = 1 mA	0		0.4	V
	I_{LOAD} = 15 mA			0.8[1]	V

[1] Guaranteed by design; not production tested.

4.4.3 Supply Current

Parameter	Condition	Min	Typ	Max	Unit
V3P3A + V3P3D current	Normal Operation, **V3P3**=3.3V, ICE Disabled		8.1	10.3	mA
V3P3A + V3P3D current vs. MPU clock frequency	Same conditions as above		0.5		mA/ MHz
V3P3A + V3PD current, Write Flash	Normal Operation as above, except write Flash at maximum rate, ADC & CE Disabled		9.1	10	mA

4.4.4 Crystal Oscillator

Parameter	Condition	Min	Typ	Max	Unit
Maximum Output Power to Crystal	Crystal connected			1	μW
XIN to XOUT Capacitance			3		pF
Capacitance to GND XIN XOUT			 5 5		 pF pF

4.4.5 VREF

Unless otherwise specified, *VREF_DIS*=0

Parameter	Condition	Min	Typ	Max	Unit
VREF output voltage, VNOM(25)	Ta = 22ºC	1.193	1.195	1.197	V
VREF chop step				50	mV
VREF output impedance	*VREF_CAL* =1, I_{LOAD} = 10 μA, -10 μA			2.5	kΩ
VNOM definition*	$VNOM(T) = VREF(22) + (T-22)TC1 + (T-22)^2 TC2$				V
VREF temperature coefficients TC1 TC2		124.4 - 2.435*TRIMT -0.265 + 0.00106*TRIMT			 μV/ºC μV/°C^2
VREF aging			±25		ppm/ year
VREF(T) deviation from VNOM(T) $\frac{VREF(T)-VNOM(T)}{VNOM}\frac{10^6}{62}$	Ta = -40ºC to +85ºC	-40[1]		+40[1]	ppm/º C

* This relationship describes the nominal behavior of VREF at different temperatures.

4.4.6 ADC Converter, V3P3 Referenced

VREF_DIS=0, LSB values do not include the 9-bit left shift at CE input.

Parameter	Condition	Min	Typ	Max	Unit
Recommended Input Range (Vin-**V3P3A**)		-250		250	mV peak
Voltage to Current Crosstalk: $\frac{10^6 * Vcrosstalk}{Vin}\cos(\angle Vin - \angle Vcrosstalk)$	*Vin* = 200 mV peak, 65 Hz, on A0 *Vcrosstalk* = largest measurement on A1 or A3	-10[1]		10[1]	µV/V
THD (First 10 harmonics) 250 mV-pk 20 mV-pk	Vin=65 Hz, 64 kpts FFT, Blackman-Harris window		 -75 -90		 dB dB
Input Impedance	Vin=65 Hz	40		90	kΩ
Temperature coefficient of Input Impedance	Vin=65 Hz		1.7		Ω/°C
LSB size	*FIR_LEN=0* *FIR_LEN=1*		357 151		nV/LSB
Digital Full Scale	*FIR_LEN=0* *FIR_LEN=1*		±884736 ±2097152		LSB
ADC Gain Error vs %Power Supply Variation $\frac{10^6 \Delta Nout_{PK}\ 357nV/V_{IN}}{100 \Delta V3P3A/3.3}$	Vin=200 mV pk, 65 Hz V3P3=3.0V, 3.6V			50	ppm/%
Input Offset (Vin-**V3P3A**)		-10		10	mV

4.4.7 Temperature Sensor

Parameter	Condition	Min	Typ	Max	Unit
Nominal Sensitivity (S_n)	*FIR_LEN=0* *FIR_LEN=1*		-669 -1585		LSB/ºC
Nominal (N_n)†	*FIR_LEN=0* *FIR_LEN=1*		+429301 +1017558		LSB
Temperature Error $ERR = T - \left(\frac{(N(T) - N_n)}{S_n} + T_n\right)$	T_A = -40ºC to +85ºC Tn = 25°C	-10[1]		+10[1]	ºC

† N_n is measured at T_n during calibration and is stored in MPU or CE for use in temperature calculations.

[1] Guaranteed by design; not production tested.

4.5 Timing Specifications

4.5.1 RAM and Flash Memory

Parameter	Condition	Min	Typ	Max	Unit
CE DRAM wait states	CKMPU = 4.9152 MHz	5			Cycles
	CKMPU = 1.25 MHz	2			Cycles
	CKMPU = 614 kHz	1			Cycles
Flash write cycles	-40 °C to +85 °C	20,000			Cycles
Flash data retention	25 °C	100			Years
Flash data retention	85 °C	10			Years
Flash byte writes between page or mass erase operations				2	Cycles

4.5.2 RESET

Parameter	Condition	Min	Typ	Max	Unit
Reset pulse fall time				1	µs
Reset pulse width		5			µs

4.5.3 Typical Performance Data

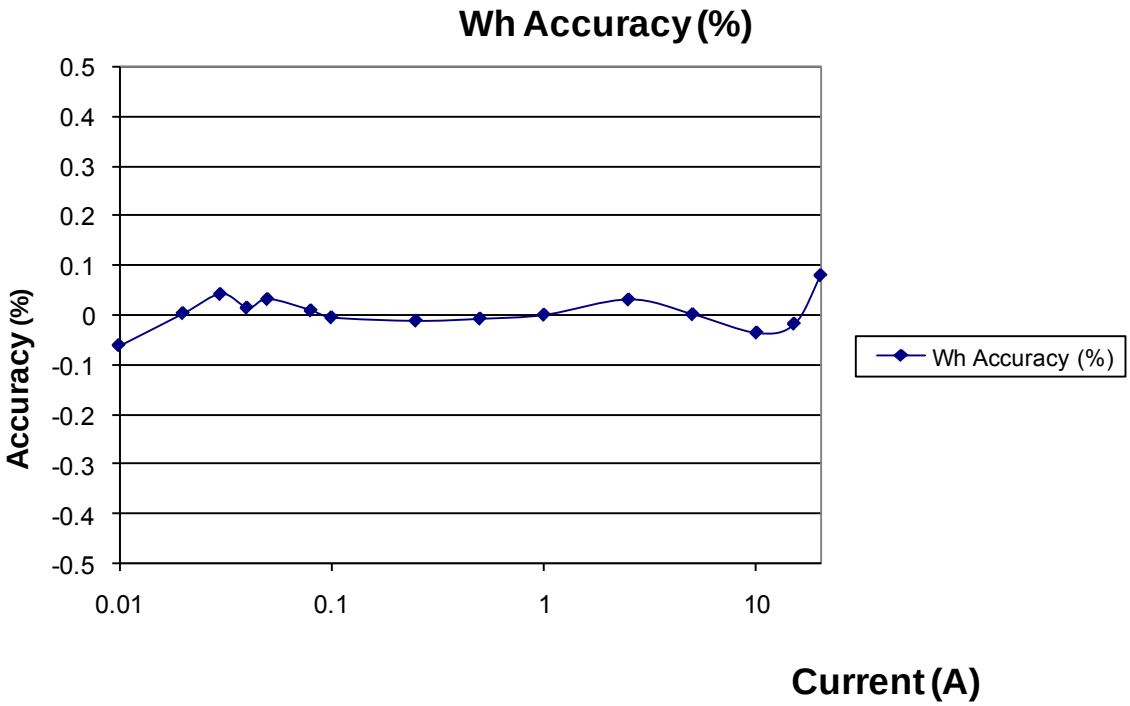


Figure 15: Wh Accuracy, 10 mA to 20 A at 120 V/60 Hz and Room Temperature Using a 4 mΩ Current Shunt

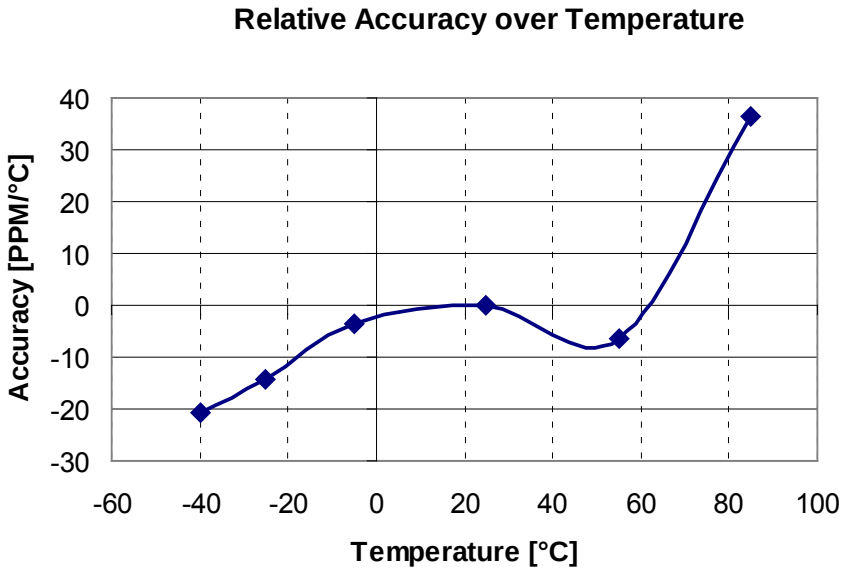


Figure 16: Typical Measurement Accuracy over Temperature Relative to 25°C

5 Packaging

5.1 Pinout

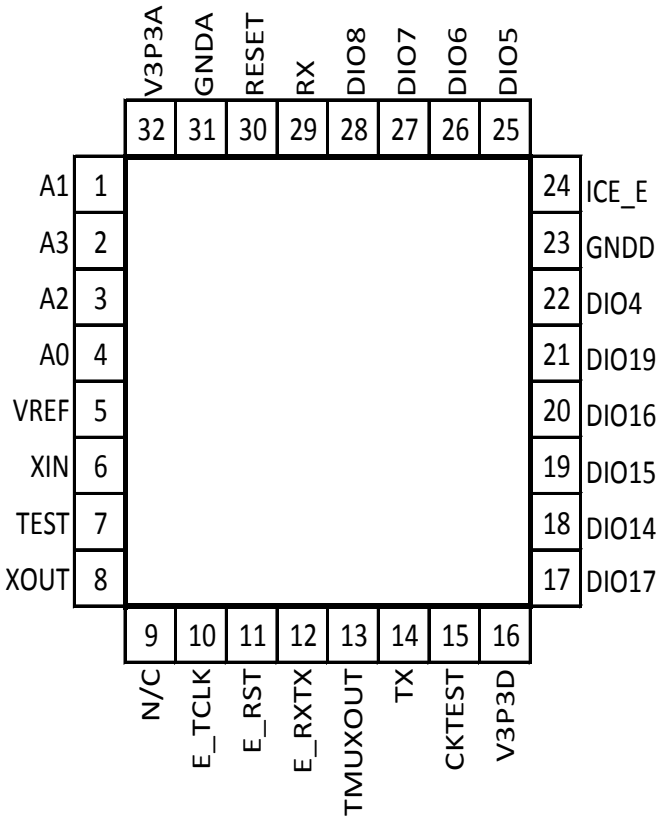
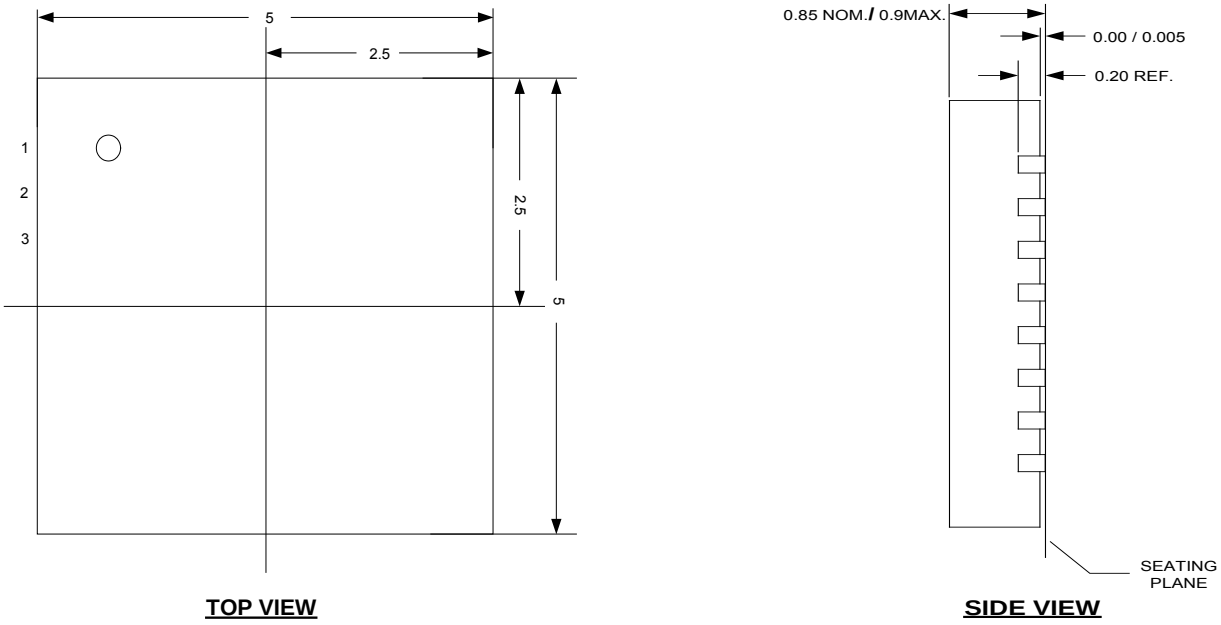
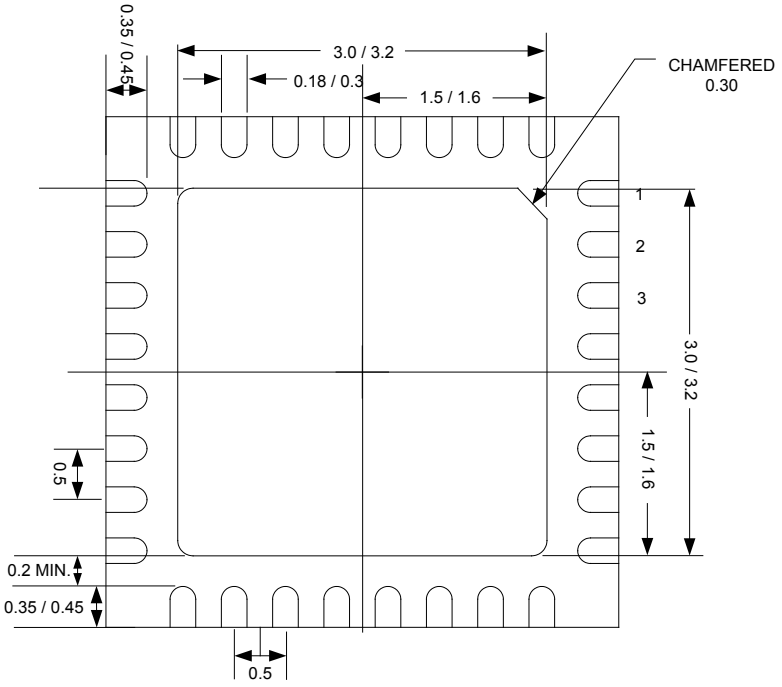


Figure 17: 32-Pin QFN Pinout

5.2 Package Outline (QFN 32)

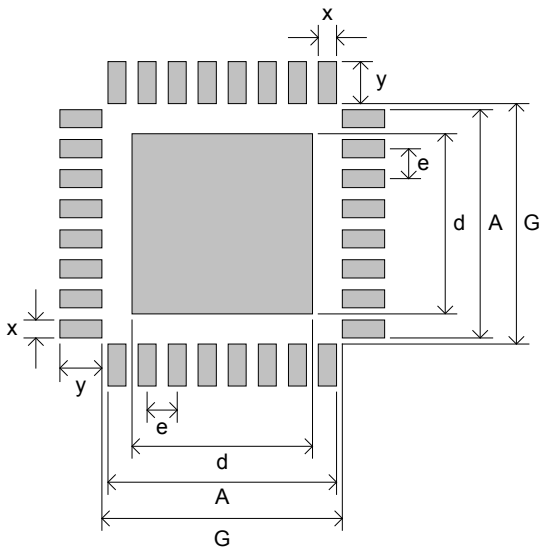




NOTE: Controlling dimensions are in mm.

Figure 18: Package Outline (QFN 32)

5.3 Recommended PCB Land Pattern for the QFN-32 Package



Symbol	Description	Min	Typ	Max
e	Lead pitch		0.50 mm	
x			0.28 mm	0.28 mm
y			0.69 mm	
d	See Note 1		3.00 mm	
A				3.78 mm
G		3.93 mm		

Note 1: Do not place unmasked vias in region denoted by dimension “d”.

Note 2: Soldering of bottom internal pad not required for proper operation of either commercial or industrial temperature rated versions.

Figure 19: Recommended PCB Land Pattern Dimensions

6 Pin Descriptions

6.1 Power/Ground Pins

Name	Type	Circuit	Description
GNDA GNDD	P	–	These pins should be connected directly to the ground plane.
V3P3A V3P3D	P	–	A 3.3V power supply should be connected to these pins.

6.2 Analog Pins

Name	Type	Circuit	Description
A0, A1, A2, A3	I	5	Sense Inputs: These pins are voltage inputs to the internal A/D converter. Typically, they are connected to either the outputs of current sensors or the outputs of resistor dividers (voltage sensors). **Unused pins must be connected to V3P3.**
VREF	O	8	Voltage Reference for the ADC. This pin is left unconnected. Never use as an external reference.
XIN XOUT	I	7	Crystal Inputs. A 32 kHz crystal should be connected across these pins. Typically, a 27 pF capacitor is also connected from each pin to GND. It is important to minimize the capacitance between these pins. See the crystal manufacturer datasheet for details.

Pin types: P = Power, O = Output, I = Input, I/O = Input/Output
The circuit number denotes the equivalent circuit, as specified under “I/O Equivalent Circuits”.

6.3 Digital Pins

Name	Type	Circuit	Description
DIO4 DIO5 DIO6 DIO7 DIO8 DIO14 DIO15 DIO16 DIO17 DIO19	I/O	3, 4	DIO pins. **If unused, these pins must be configured as DIOs and set to outputs by the firmware.**
E_RXTX, E_RST	I/O	1, 4	Emulator port pins (when ICE_E pulled high) .
E_TCLK	O	4	
ICE_E	I	2	ICE enable. When zero, E_RST, E_TCLK, and E_RXTX are disabled. For production units, this pin should be pulled to GND to disable the emulator port. This pin should be brought out to the programming interface in order to create a way for reprogramming parts that have the *SECURE* bit set.
CKTEST	O	4	Clock PLL output.
TMUXOUT	O	4	Digital output test multiplexer.
RESET	I	3	This input pin resets the chip into a known state. For normal operation, this pin should be pulled low. To force the device into reset state, it should be pulled high. Refer to Section 3.6 for RESET pin connections, use, and relevant external circuitry.
RX	I	3	UART input. **If unused, this pin must be terminated to V3P3 or GND.**
TX	O	4	UART output.
TEST	I	7	Enables Production Test. **Must be grounded in normal operation.**

Pin types: P = Power, O = Output, I = Input, I/O = Input/Output
The circuit number denotes the equivalent circuit, as specified on the following page.

7 I/O Equivalent Circuits

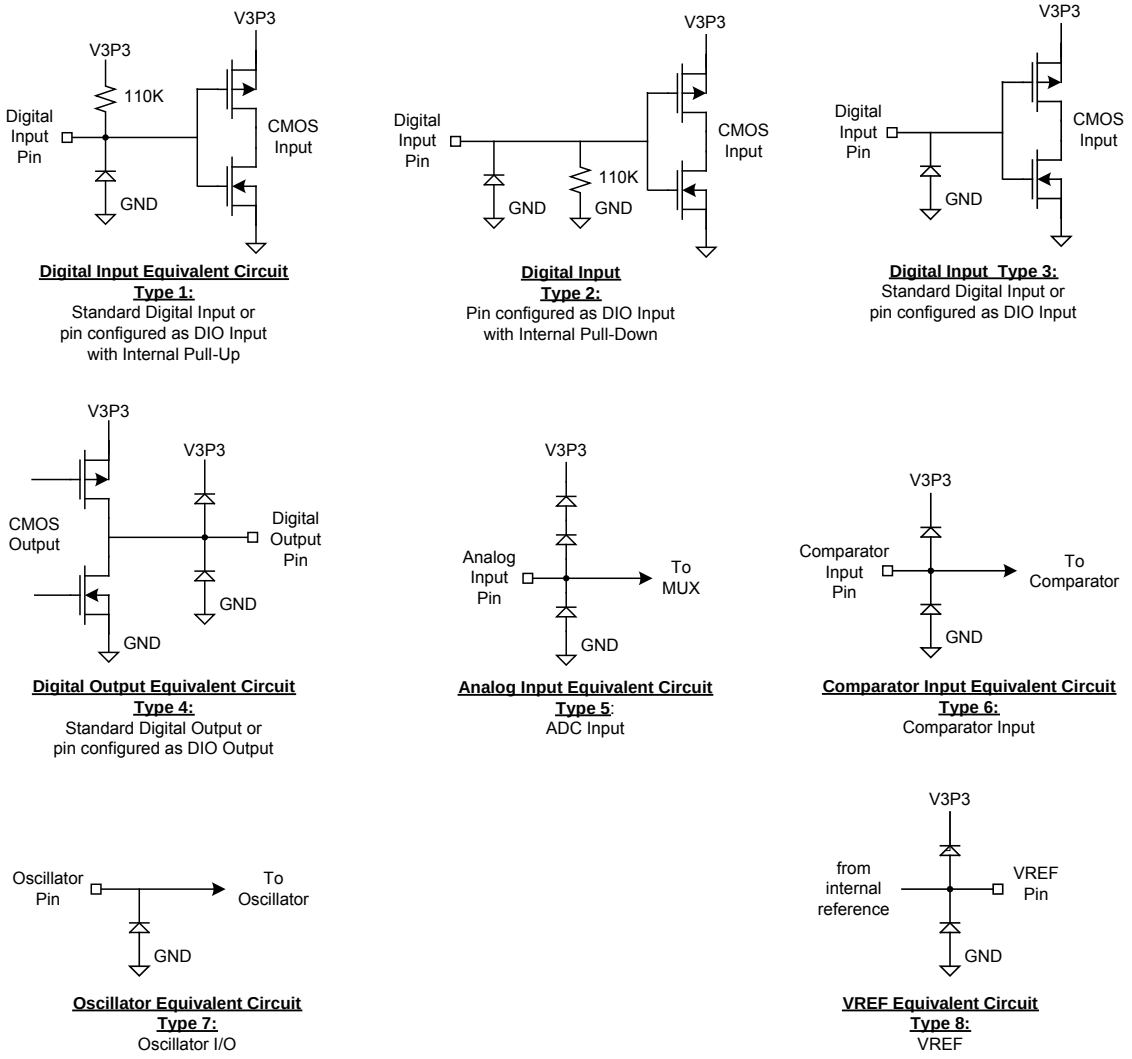


Figure 20: I/O Equivalent Circuits

8 Ordering Information

Part	Package	Option	Ordering Number	IC Marking
78M6613	32-pin QFN (Lead(Pb)-Free)	Bulk	78M6613-IM/F	78M6613-IM
		Tape & Reel	78M6613-IMR/F	
		*Programmed, Bulk	78M6613-IM/F/P	
		*Programmed, Tape & Reel	78M6613-IMR/F/P	

*Contact the factory for more information on programmed part options.

9 Contact Information

For more information about Maxim products or to check the availability of the 78M6613, contact technical support at **www.maxim-ic.com/support**.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
1.0	11/10	First publication.	—
1.1	3/11	In Section 6.3, corrected the description of the RESET pin.	30

Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600

APPENDIX E. DATA AND CHARTS

The data and charts are in the following files:

- A5 Normalized (Elect Demand & Illuminance).xls
- Annual Normalization w_savings&payback (Electrical Demand).xls
- Monitored Periods Normalization (Electrical Demand).xls
- PS2500 & T&D data Phase 1.xls
- PS2500 & T&D data Phase 2.xls
- PS2500 & T&D data Phase 3.xls
- PS2500 & T&D data Phase 4.xls
- PS2500 & T&D data Phase 5.xls
- PS2500 all phases.xls
- Typical Week (Normalized).xls

The files are in the archive ET12PGE1031 ALCS in an Office Bldg App E Data and Charts.zip.

APPENDIX F. COST AND SAVINGS ANALYSIS

Cost Breakdown Provided by Enlighted

CCCOE

Total Project $27,021.96 Invoice

Materials

	Number	Cost	Total
Lamps	324	$2.38	$769.50
Dimming Ballasts	162	$26.00	$4,212.00
Control Units	162	$20.00	$3,240.00
Sensors	162	$50.00	$8,100.00
Gateways	2	$100.00	$200.00
Server	1	$1,000.00	$1,000.00
POE Switch	1	$150.00	$150.00
Eth Cables	2	$100.00	$200.00
Misc	N/A	$300.00	$300.00
			$18,172

	Time	Rate	Total
Labor			
Reballast + lamps	162	$35.00	$5,670.00
Gateways	2	$600.00	$1,200.00
Server/Switch	1	$1,500.00	$1,500.00
Comissioning	with server	$0.00	$0.00
			$8,370.00
Phase I	1	$120.00	$120.00
Phase II	1	$120.00	$120.00
Phase III	1	$120.00	$120.00
Phase IV	1	$120.00	$120.00
			$480.00

Total	**$27,022**

Job No: 1316.57 Date: 3/29/2013 By: JBG Check: PRJ 03/12/13
File: savings&payback (normalized).xls Sheet: Savings Tables

For 3 Weeks (data normalized to exclude anomalies)

Power Consumption (kWh)	Baseline (Phase 1)	Phase 2	Savings	Phase 3	Savings	Phase 4	Savings	Phase 5	Savings	*Savings b/w P1 & P5*
Panel H3S	1809	1335	26%	1310	2%	1028	21%	1019	1%	44%

Annualized

Power Consumption (kWh)	Baseline (Phase 1)	Phase 2	Savings	Phase 3	Savings	Phase 4	Savings	Phase 5	Savings	*Savings b/w P1 & P5*
Panel H3S	29178	21546	26%	21149	2%	16514	22%	16414	1%	44%

Incremental Energy Savings from Phase 1	Phase 2		Phase 3		Phase 4		Phase 5	
from annual extrapolation	kWh Saved	% Saved	kWh Saved	% Saved	kWh Saved	% Saved	kWh Saved	% Saved
Panel H3S	7632	26%	8029	28%	12664	43%	12763	44%

Energy Savings between Phases	Phases 1 & 2		Phases 2 & 3		Phases 3 & 4		Phases 4 & 5	
from annual extrapolation	kWh Saved	% Saved	kWh Saved	% Saved	kWh Saved	% Saved	kWh Saved	% Saved
Panel H3S	7632	26%	397	2%	4635	22%	99	1%

Payback Period with Utility Rate of $0.16625/kWh
Based on averged combined energy and demand charges for A10 rate schedule.

(REPORT PAYBACK)

Incremental Energy Savings from Phase 1	kWh Saved/yr	Payback Period (yrs)	Payback Period (yrs)
Phase 2	7632	21	21
Phase 3	8029	20	20
Phase 4	12664	13	13
Phase 5	12763	13	13
Energy Savings between Phases	kWh Saved/yr	Payback Period (yrs)	Payback Period (yrs)
Phase 1 - Phase 2	7632	13	13
Phase 2 - Phase 3	397	2	2
Phase 3 - Phase 4	4635	0	<1
Phase 4 - Phase 5	99	7	7

Cost Data

Phase	**Incremental Cost (by Phase)**		**Cost between Phases**
1	$10,651.50		-
2	$26,661.50		$16,010.00
3	$26,781.50		$120.00
4	$26,901.50		$120.00
5	$27,021.50		$120.00

Cost Effectiveness

Phase	**kWh Saved/$ Spent for Measures from baseline**		**kWh Saved/ $ Spent for Measures between Phases**
1	-		-
2	0.286		0.477
3	0.300		3.310
4	0.471		38.625
5	0.472		0.826

APPENDIX G. SURVEYS

Survey Report - CCCOE Lighting Survey

INTRODUCTION

The Light Right lighting satisfaction survey tool is a free resource for building owners, operators, or researchers to use to determine building occupants' lighting satisfaction, diagnose existing or potential problems, and improve indoor lighting quality.

The Light Right Survey Tool is intended to help users make more informed decisions about lighting upgrades, including how to combine quality improvements with energy-saving strategies. This report is broken out into 7 sections:

1. **Survey Sample Statistics:** Describe the demographics of the survey sample, determine the validity of the survey, and report errors, if any.
2. **Human Factors Considerations:** Analyze occupant characteristics such as age, gender, primary job, type of workspace, etc. to highlight specific lighting considerations for your building occupants.
3. **Daylight & Views:** Identify your building occupants' accessibility to daylight and views and how they control their immediate daylighting environment, and assess their satisfaction with their daylighting access and controls.
4. **General Lighting:** Assess your building occupants' preference and satisfaction with their general lighting, including the overhead and task lighting systems.
5. **Controls:** Assess your building occupants' preference and satisfaction with the lighting controls being used.
6. **Light Levels:** Analyze your building occupants' ratings of light levels to perform various tasks, general atmosphere and uniformity on work surfaces.
7. **Image & Atmosphere:** Assess how well the lighting contributes to organizational image and the general lighted atmosphere in the workplace.

Section 1: SURVEY SAMPLE STATISTICS

This survey was specifically designed to assist survey managers in identifying problems with their lighting system. Depending on sample size and response rates, you will be able to view the results with varying degrees of confidence. The desired response rate that is referenced in the web application is intended to give you 90% confidence with a 15% margin of error. These calculations are based on the response rate for the question "Overall, is the lighting comfortable?" with the assumption that 70% of respondents would answer "yes." In order to establish statistical significance for any other question or groups of questions in this survey, separate statistical analyses are advised.

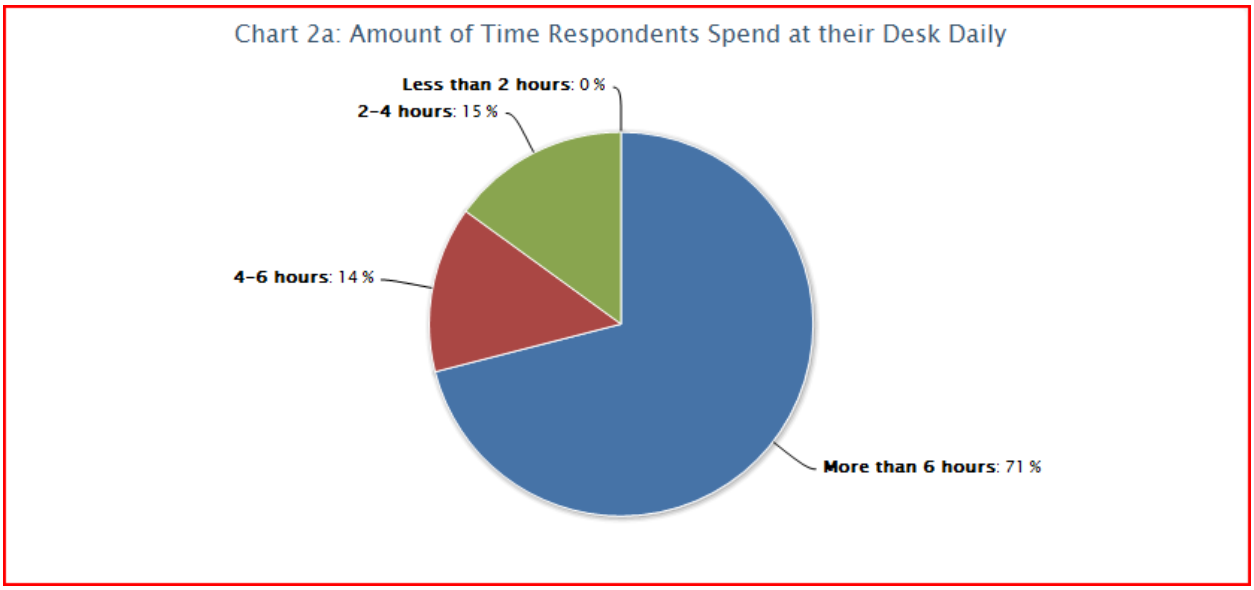
Generally, the more people that respond to the survey, the more confident you can be in the results. Keep in mind, however, that all questions are not mandatory and while you might have 100 respondents, that does not mean that every one of them answered each question. Cross-reference the raw data excel document that is available on your account at https://www.lightingsolutions.energy.gov/cls-survey to see how many people answered a specific question.

When drawing conclusions from this data, not only should the number of respondents be considered, but the demographics of the respondents. If the data is weighted heavily due to a non-response bias it will not be representative of the entire sample. Of the respondents, 71% are female and 14% are male. 0% are under the age of 30. Are these statistics representative of your building occupants?

Section 2: HUMAN FACTORS CONSIDERATIONS

People are a company's most valuable resource. There is a large cost associated with hiring and training employees, and while there are many considerations when it comes to achieving high levels of personnel retention, keeping your employees happy and comfortable is of the utmost importance. Research suggests a link between employee job satisfaction and their lighting (Boyce et. al, 2003).

More than 6 hours: 71 %



More than 6 hours: 71 %**4-6 hours**: 14 %**2-4 hours**: 15 %**Less than 2 hours**: 0 %
Chart 2a: Amount of Time Respondents Spend at their Desk Daily

71% of people spend more than six hours at their desk daily. In order to meet their visual needs and ensure that they are comfortable, lighting quality is of the utmost importance. Lighting quality issues are addressed later in this section, *Daylight and Views, and Image and Atmosphere*.

Visual Needs

Occupants that spend a lot of time filing and locating paper documents have more demanding visual needs than those that spend more time on their computer. These areas should be provided with higher ambient light levels that are more uniform than for computer screen tasks alone. Because the visual tasks in these areas are most often on a vertical plane (such as the tab of a file folder), it also makes sense to provide more diffuse light that delivers vertical footcandles more effectively. Light reflected from light-colored surfaces is an effective means of delivering diffuse light, so adding some indirect lighting or washing a light-colored wall with light can be an excellent solution in printer and copier areas, file storage areas, and similar spaces in the office.

Table 2a: Job Description and Office Type

	PRIVATE OFFICE	OPEN OFFICE	OTHER
People management, leadership, and/or training	100%	0%	0%
Computer aided design, engineering, or software development	0%	0%	0%
Combination of computer work, paper tasks, phone calls and meetings	0%	67%	0%
Facility management	0%	33%	0%
Other	0%	0%	0%

Different jobs have different lighting needs in an office building. Employees who are primarily managers of people, or those that are involved with face-to-face discussions, training, and personnel issues spend more time looking at faces for cues of comprehension and attitude. It's important that faces be readable and that faces look pleasant. Vertical footcandles delivered through diffuse or reflected light is very helpful.

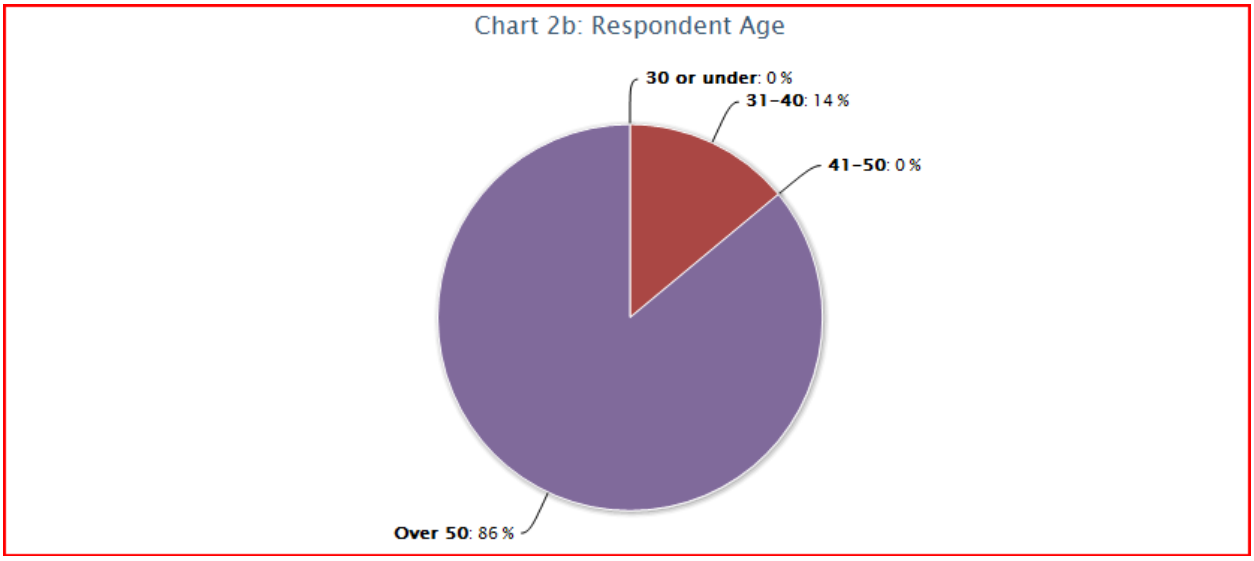
Diffuse lighting, however, can interfere with computer screen viewing. Some CAD tasks require differentiating colored lines on a black background screen, and too much diffuse lighting can superimpose a bright screen reflection that washes out the screen image. In computer-screen-critical spaces, consider low ambient light levels, and more local task lighting that can be adjusted to deliver light on the desktop but away from the user's eyes and screen.

Most office spaces have a combination of computer and paper-based tasks. A happy medium of ambient lighting with a moderate amount of diffusion plus localized task lighting over which the user has control, may be a solution that fits most users.

Demographics

To ensure that your building occupants' needs are being met, you will also need to understand who the building occupants are, and what their age groups are.

Over 50: 86 %



30 or under: 0 %31–40: 14 %41–50: 0 %Over 50: 86 %
Chart 2b: Respondent Age

Lighting needs change as we grow older, and the aging eye needs higher light levels, better uniformity of horizontal light levels, and improved task contrast. Of the respondents, 86% are above the age of 50, which means providing sufficient light for the building's occupants is especially challenging and important.

One or more personal task lights should be provided to the over 50 population as well as any younger employees that have visual difficulties. Providing desktop task lights upon request is an effective way of increasing general occupant satisfaction. It also ensures that worker productivity will not be reduced because they are struggling to see their work clearly.

Visual Comfort and Glare

Glare can be discomfort directly experienced by the employee, usually from excessively bright luminaires or windows, or it can be a bright patch of light reflected from the computer screen and obscuring the screen image. Glare issues can inhibit productivity and comfort, and corrections should be made to decrease glare.

Window Glare (of those experiencing glare)

OPTION	PERCENT
Direct	33
Reflected	67

Overhead Lighting Glare (of those experiencing glare)

OPTION	PERCENT
Direct - Local Overhead	33
Direct - Byond Workspace	33
Reflected	34

Task Lighting Glare (of those experiencing glare)

OPTION	PERCENT
Direct	60
Reflected	40

If window glare is reported, check to see if each individual employee can reorient their workstation so that they are not facing the bright window and that their computer screen is not facing the bright window (this usually means the direction of the employee's gaze toward the computer screen is parallel to the window). Alternatively, operable shading with horizontal blinds, mesh shades, drapes, etc. can successfully block glare from sun and sky. These should be considered before applying film to darken windows, since the film can make the office interior look gloomy, and even low-transmittance films cannot block glare from direct sun.

Direct glare from task lighting is a problem when the bright light source or lens is visible, but can be alleviated by shielding the source with an opaque vertical shield on the side facing the user. Sometimes the task light is mounted too high and is therefore putting light into the user's eyes rather than just the work surface. A desktop task light can be provided instead. Reflected glare from the task surface is known as a veiling reflection, and is only a serious issue if the occupant uses shiny paper such as glossy photos or magazine pages. Veiling reflections are most effectively remedied by changing the task light to one that is designed to redirect light parallel to the length of the task light, or turning off the fixed undercabinet task light and mounting a movable-head portable task fixture to the desk top instead.

Overhead glare is discomfort caused by overhead light fixtures. If an employee complains of glare and it is alleviated by the brim of a baseball cap, this may be the problem. It is caused by an excessively bright bare lamp or lens or reflective surface that is visible. The solution is to spread the light over a larger area by installing a diffusing lens in front of the bare lamp(s) or by reducing the output of the lamp so that the unit brightness is reduced. This can be done with a low-output fluorescent ballast or a dimming ballast, but do this only if the Light Level section validates that occupants regard the lighting as being too bright in addition to glaring.

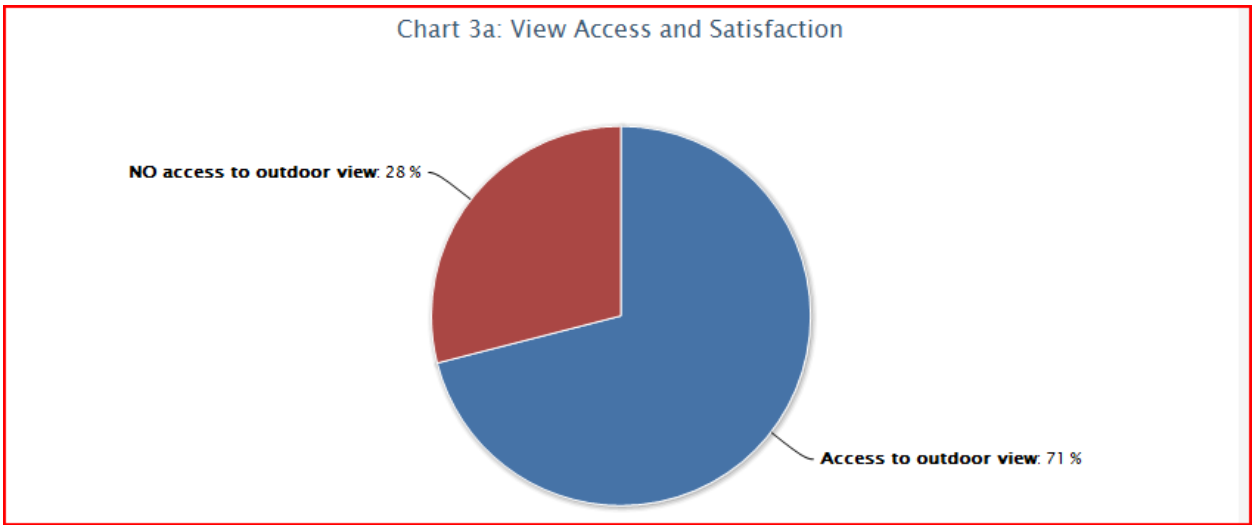
Discomfort glare also produces a painful reaction, but this comes from fixtures that are within the normal field of view (i.e. not looking upward). The cause is light fixtures that emit too much

light at high angles, rather than directing most of their light downward (for a recessed fixture, straight down is considered 0°, and the ceiling line is 90°). Discomfort glare is usually caused by excessive light emitted from 60° up to 90°.

- Replace luminaires (ensure that appropriate light levels are being met and verify that the optical characteristics of the replacement luminaire are designed to minimize light emitted above 60°)
- If possible, replace the lens or louver with one that has better shielding. For example, standard prismatic lenses can be replaced with better-quality acrylic lenses designed for computer-screen-intensive areas. These lenses direct more light downward and less at high angles. Some parabolic louvers can be replaced with louvers with more cells, which will improve the shielding angle. It's best to install a few of them and verify that they will work, before committing to a large quantity order.

Section 3: DAYLIGHT AND VIEWS

Access to daylight and a view can play a role in job satisfaction, and therefore employee retention.



Access to outdoor view: 71 %**NO access to outdoor view**: 28 %
Chart 3a: View Access and Satisfaction

Do you like the view from the window? (of those with access to an outdoor view)

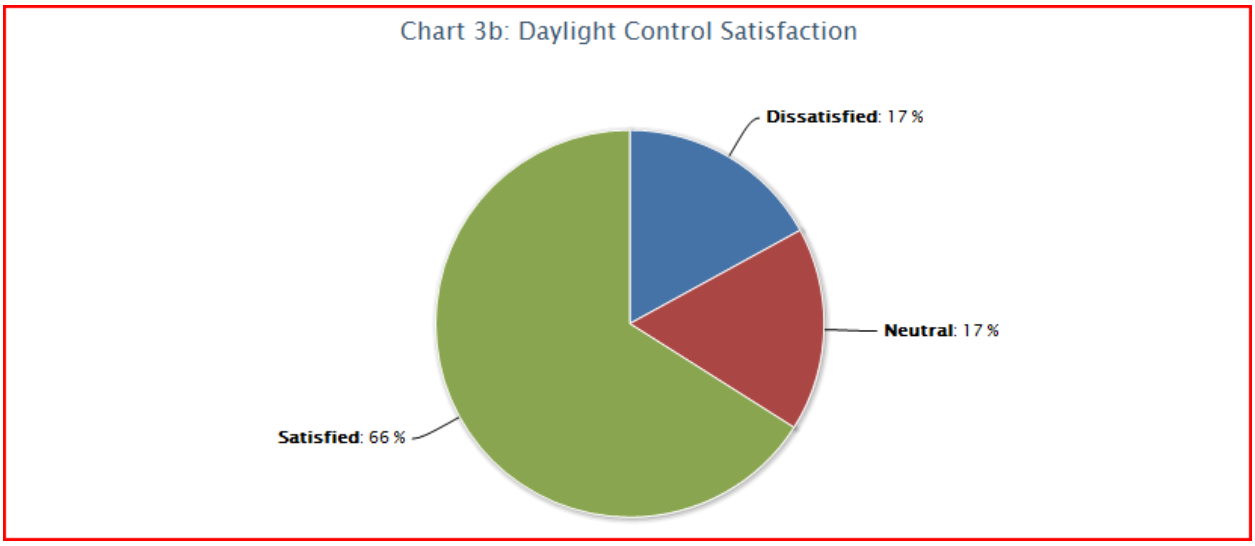
Like the view	100%
Do NOT like the view	0%

0% of respondents do not have access to a view. Consider changing the space layout to improve daylighting accessibility. This can be done by locating circulation space along the window walls so that employees have a view out as they go for meetings or coffee breaks. Secondary circulation space can run perpendicular to the windows, allowing employees to look out from their workstations down the aisle toward the windows. Run workstation spines perpendicular to the windows, and reduce non-spine workstation panel heights to 48", allowing staff to see windows even if they are 4 or 5 workstations in from the windows. Locate private offices in the center of the floor plan rather than along the window walls, giving more highly-populated open office areas priority for view. Consider transparent window glass in private offices and meeting rooms, with shades for darkening and privacy.

Shading and daylighting control

It is important to provide occupants access to daylighting and view when possible, and it is also vital to provide them with an effective means of controlling the daylight to mitigate potential glare. Daylight shading satisfaction will play a role in the occupant's overall satisfaction with the lighting system. The following set of charts will help determine if the daylight control system is well accepted.

Satisfied: 66 %



Dissatisfied: 17 %**Neutral**: 17 %**Satisfied**: 66 %
Chart 3b: Daylight Control Satisfaction

Shading Types of Dissatisfied Occupants:

Manual blinds (e.g., Venetian blinds)	100%
Manual window shades (e.g., roller shades)	0%
Automatic blinds or shades	0%
Other (please specify)	0%
No shading control	0%

An appropriate shading system can help to decrease glare associated with daylight (see *Human Factors Considerations* section to determine if glare caused by daylight is a substantial

problem). In addition, shading can either provide or inhibit the opportunity for daylight harvesting techniques to control the electric lighting.

Chart 3c: Window Shading System

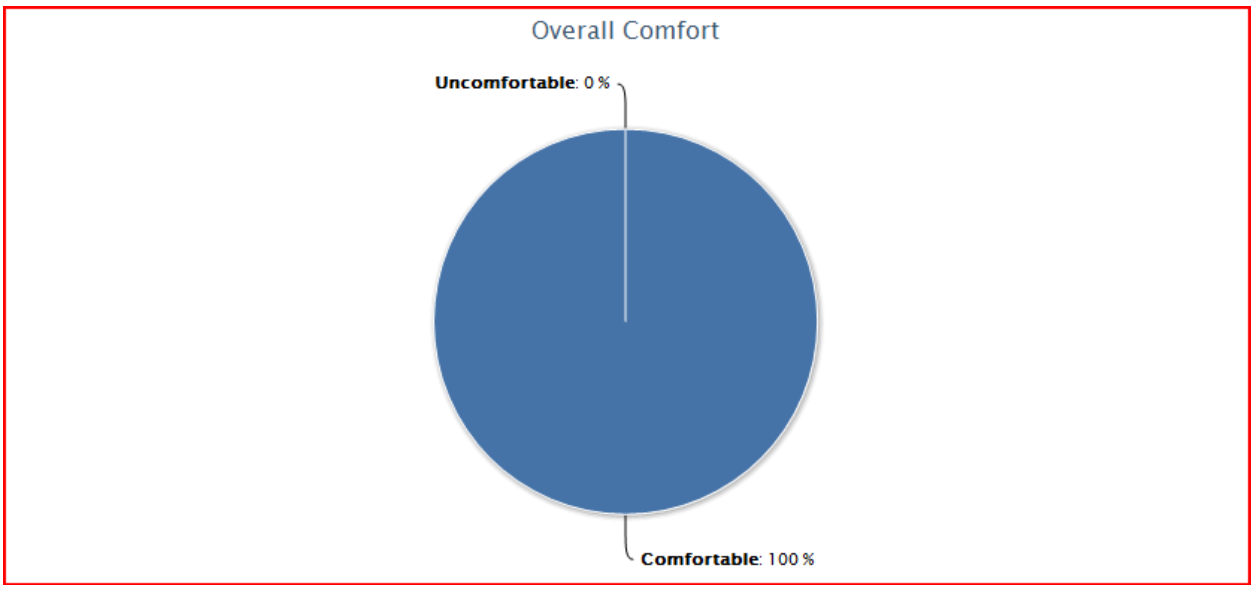
If you are considering implementing a daylight harvesting control system, be sure to update your window shading system as well. 86% of occupants with access to daylight control their shading system manually, which means that the shades could remain closed. In order to reap the maximum benefits of daylight harvesting the shading system should either be automated or a system should be put in place to decrease occupant intervention. Exterior shading could prevent the shades from being closed by occupants as frequently, but facilities personnel should also be advised to open the shades/blinds daily.

If an automatic system is implemented, it should be noted that every building is different and an expert should be involved with commissioning and recommisisoning the system over the course of an entire year. Also, a system needs to be put in place where occupants can register a complaint and have it resolved quickly if there is an glare that they cannot control due to the automated nature of the shades.

Section 4: GENERAL LIGHTING

The chart below represents all of the survey respondents that shared their opinion about their overall comfort regarding the lighting system. If there are different overhead lighting systems in the building, it will be valuable to compare the level of comfort for each system. In addition to overhead lighting, task lighting and wall lighting both play a role in the overall comfort of the lighting system, so be sure to consider these multiple components if your occupants are expressing dissatisfaction.

Comfortable: 100 %

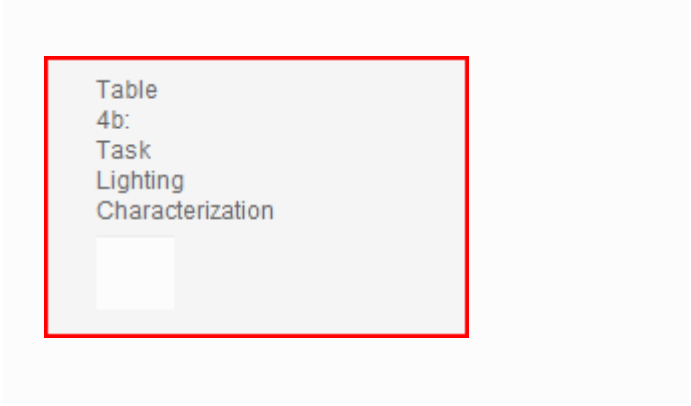


Comfortable: 100 %**Uncomfortable**: 0 %

Table 4a: Overhead Lighting Characterization

Table 4a: Overhead Lighting Characterization

Table 4b: Task Lighting Characterization



Task lighting is an extremely effective way to ensure sufficient light is being provided. There are, however, specific problems that can result from the use of task lighting. Reflected glare from computer screens, veiling reflections, direct glare, and high contrast ratios can all be caused by poor task lighting products or their positioning, so it is important to choose and install task lighting carefully. Ideally, bright lenses or lamps of the task light in use should not be visible to the workstation occupant, or the occupant''s neighbor. The light from the luminaire should be spread evenly across a large area of the desk so that it does not produce a bright pool of light. (High contrast variations in light can cause eye fatigue.) Finally, if the task light (especially an undercabinet light) also illuminates the workstation panel, this helps reduce contrast and softens shadows cast by hands and arms on the desktop.

The illumination of walls in an office environment also plays a role in the occupant's perception of the lighting system. Often, additional wall lighting is incorporated in the lighting system to reduce brightness contrast in the field of view (that is, help even out the lighting in a space in order to improve visual comfort), and produce the cheerful appearance that comes from lighted vertical surfaces. Dim walls or dark walls with sharp-edged light scallops on them may lead to a response that the space feels gloomy. Of the respondents that do not find the overall lighting system comfortable:

Chart 4c: Wall lighting Characteristics

Section 5: CONTROLS

Overhead Lighting Controls

Lighting controls are a very important component of the lighting system. They provide great potential to save energy but can also greatly impact the acceptability of the lighting from the user's perspective. First, take a look at the following charts to understand the current lighting controls and the satisfaction associated with them.

Table 5a: Controls by Space Type

	PRIVATE OFFICES	OPEN OFFICES / HIGH PARTITIONS	OPEN OFFICES / LOW PARTITIONS	OTHER (PLEASE SPECIFY)
Switch at wall	20%	0%	80%	0%
Handheld remote	0%	0%	0%	0%
Interface at your computer	0%	0%	0%	0%
Automated system / controlled by building management	33%	33%	34%	0%
Other (please specify)	0%	0%	100%	0%

Chart 5a: Satisfaction with Ability to Control Overhead Lights

Energy saving controls need to be applied correctly in order to retain occupant satisfaction. Controls that give the occupants more flexibility can increase energy savings and should be incorporated into the system if possible. Evaluate the capabilities of the current lighting controls and consider the following for the satisfaction of the occupants:

All buildings should have automatic shut-off- The implementation will depend on the specific building. Scheduling the lights to turn off after hours but still providing occupants with override switches allows you to meet this goal, if override switches are conveniently located and the circuiting of the lighting allows for overriding small areas of lights. Occupancy-based controls, especially in smaller enclosed spaces such as conference rooms or private offices can provide additional energy savings when these spaces are used intermittently during business hours. "Occupancy" sensors automatically turn ON and OFF, and "vacancy" sensors require users to turn the lights on but automatically switch lights off after the sensor detects no motion. Vacancy sensors generally save more energy than occupancy sensors. Consider implementing these technologies in private offices, meeting rooms, copy rooms, restrooms, kitchens, and storage spaces, for example. They can even be considered for some open office and corridor areas especially if output can be dimmed to a low level (not fully off).

Consider providing occupants with personal controls- Everybody has a different preference when it comes to light levels, and providing occupants the ability to control the light in their space has been demonstrated to improve job and environmental satisfaction among office workers (Veitch et. al) and to save energy where employees prefer lower light levels. In shared spaces, the implementation can be challenging because the light above one workstation may actually affect the light level at the adjacent workstation, so one person's choice may not suit his or her neighbor.

- Provide Individual Control- In private spaces provide multi-level switching or dimming controls at the wall. In open offices give occupants control over the light(s) immediately above them via handheld remote or control software that resides on their computer.
- Provide Automatic Controls- Spaces with good-quality daylight are opportunities for automatic energy savings in areas along the window walls. Multi-level switching or (preferably) dimming controls on luminaires within 15' of the window allow for dimming luminaires with a minimum of distraction to employees. An experienced professional should recommend the specification, location, and orientation of daylighting controls. Competent commissioning is essential for satisfactory operation.

Task Lighting Control Characterization and Satisfaction:

The different types of task lighting are represented in the bar chart below. Each task lighting type has controls associated with it and that is shown in the table below. For each task lighting type, see the pie charts that illustrate controls satisfaction. If there is a specific issue with lighting controls associated with a task lighting type it will be evident below

Chart 5c: Task Lighting Control Type
Chart 5d: Ability to Control Task Lights

Section 6: LIGHT LEVELS

Achieving the appropriate light levels for the multitude of tasks that might be occurring in a space can be challenging. Here is a breakdown of according to the occupants of your building:

When occupants feel that the lighting is too bright for specific tasks, providing them control of the lights is the ideal way to ensure that they are comfortable. If the lighting is too dim for paper tasks or filing/locating files, task lighting might mitigate the issue. If there are complaints that it's difficult to read from a computer screen, then the problem lies in the screen size, resolution, or software graphic display, rather than the lighting. If there is not sufficient light for face-to-face conversations, or typing on a keyboard, it could indicate a need for changes in the general lighting system.

Providing appropriate light levels and uniformity are important to support occupant productivity. Of the occupants that responded to the survey, here is the range of opinions regarding work surface uniformity.

Section 7: IMAGE AND ATMOSPHERE

The lighting in a space can set a certain mood and contribute to occupant comfort or stress. Lighting also plays a major role in portraying an image of the company to both employees and outsiders.

Sometimes occupants will report flicker from fluorescent lamps, when the perception actually stems from overhead glare or a lighting system that is too-uniform and produces little shadowing that can add crispness or clarity to a lighted room. A test for this is to ask occupants to shield

their eyes as though they are wearing a baseball cap. If the perception of "flicker" disappears, the culprit may be the overhead, too-uniform lighting system. This problem can be remedied by reducing the amount of overhead ambient lighting by delamping or installing low-output ballasts, adding task lighting to the workstation, and adding accent lighting or wallwashing to highlight surrounding walls.

If occupants do not feel that the general lighting is "nice looking," replacing the luminaires with more attractive, efficient luminaires is an option to improve the appearance of the system (this should involve a lighting professional's guidance). Or, consider reducing the amount of light emitted from overhead luminaires and adding task lighting to the desks, and accent lighting or wallwashing to the walls. This will make the space appear more visually stimulating without replacing the entire overhead lighting system.

"Room surface brightness" is a term which refers to the psychological response to light patterns and light levels on ceilings and walls. If walls and ceilings are dim, the space can feel gloomy and forbidding. If walls have an uneven pattern of light and shadow, especially if the top of the wall is dark, that can also contribute to a perception that the space is unpleasant. Room surface brightness is a combination of the distribution of the light fixture, the proximity of the light fixture to the wall, and the color of the wall. Sometimes repainting a large, dark-colored wall a lighter color can fix the problem. Sometimes washing a wall evenly with light or accenting artwork on the wall is the solution. Sometimes moving the luminaire to within 2 or 3' of the wall will fix the situation.

A component of indirect lighting on a white ceiling can also increase perceived brightness, making the ceiling feel higher. If considering a new lighting system, a combination of uplight and direct light can be an energy-efficient solution that improves the cheerfulness of the space. There are other options as well, depending on the existing lighting system and its condition. Consult a lighting professional for specific recommendations.

Unnatural skin tone is usually related to the spectrum of the installed lamps. Light sources with a Color Rendering Index (CRI) greater than 80 should be installed at the next opportunity. High-performance fluorescent lamps have a high CRI value but are also more efficient in terms of Lumens-per-Watt, so it may be possible to replace the existing lamps with lower-wattage fluorescent lamps that will improve color quality while reducing energy use.

The color of emitted light (warm, neutral, cool, very cool, for example) can also affect the response to this question. Lamp color is measured in Correlated Color Temperature (CCT). "Warm" is generally around 3000K, neutral is in the range of 3500K to 4000K, cool ranges from

4000K to 5000K, and very cool is usually >5000K. The color temperature preference of the building occupants can be a guide to lamp selection and is represented in the following chart:

Color Appearance of Lighting By Fixture

Acknowledgements

The National Electrical Manufacturers Association (NEMA), Lighting Controls Association, Light Right Consortium, General Service Administration

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CCCOE Lighting Survey (Raw Data)

Questions	Answers	Respondents with Other (0)	Respondents with Parabolic (1)	Respondents with Flat lens (6)	Respondents with other (0)
Which of the following best describes the type of work that you do?					
	People management, leadership, and/or training	0	1	0	0
	Computer aided design, engineering, or software development	0	0	0	0
	Combination of computer work, paper tasks, phone calls and meetings	0	0	4	0
	Facility management	0	0	2	0
	Other	0	0	0	0
What is your age?					
	30 or under	0	0	0	0
	31 - 40	0	0	1	0
	41 - 50	0	0	0	0
	Over 50	0	1	5	0
What is your gender?					
	Female	0	0	5	0
	Male	0	1	1	0
Which of the following best describes your personal workspace?					
	Enclosed private office	0	1	0	0
	Cubicles with partitions above standing eye level	0	0	1	0
	Cubicles with partitions below standing eye level	0	0	5	0
	Other (please specify)	0	0	0	0
What type of computer screen do you have?					
	Laptop	0	0	0	0
	Flat Panel Screen	0	1	4	0
	Traditional Screen (CRT)	0	0	1	0
	Other (please specify)	0	0	1	0
On a typical day, how long are you in your personal workspace?					
	More than 6 hours	0	0	5	0
	4-6 hours	0	1	0	0
	2-4 hours	0	0	1	0
	Less than 2 hours	0	0	0	0
Are you able to see out a window while sitting in your workspace?					
	Yes	0	1	4	0
	No	0	0	2	0
Do you like the view?					
	Yes	0	1	4	0
	No	0	0	0	0
Do you sit adjacent to the window?					
	Yes	0	1	3	0
	No	0	0	1	0
Which of the following most closely resembles the overhead lighting in your immediate work space?					
	Fixture 1	0	0	0	0
	Fixture 2	0	1	0	0
	Fixture 3	0	0	6	0
	I don't see my fixture here.	0	0	0	0
Overall, is the lighting comfortable?					
	Yes	0	1	6	0
	No	0	0	0	0
Do you have task lighting?					
	Yes	0	0	3	0
	No	0	1	2	0
Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?					
	Undercabinet task light	0	0	2	0

CCCOE Lighting Survey (Raw Data)

Questions	Answers	Respondents with Other (0)	Respondents with Parabolic (1)	Respondents with Flat lens (6)	Respondents with other (0)
What type of control do you have for your task lighting?	Desktop task light	0	0	1	0
	On/Off switch	0	0	2	0
	Dimmer switch	0	0	0	0
	Other (please specify)	0	0	1	0
	Does not apply	0	0	0	0
Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.					
	Uniformly bright walls	0	0	4	0
	Uneven light distribution on walls	0	1	1	0
	Accent lighting on artwork only	0	0	0	0
	Walls are dim	0	0	0	0
	Other	0	0	0	0
	Do not know	0	0	1	0
Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?					
	Yes	0	1	6	0
	No	0	0	0	0
	Do not know	0	0	0	0
Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?					
	Yes	0	1	5	0
	No	0	0	1	0
	Do not know	0	0	0	0
If your lights turn off automatically, can you turn them back on from your immediate work area?					
	Yes	0	1	5	0
	No	0	0	0	0
	Do not know	0	0	0	0
Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?					
	Yes	0	1	3	0
	No	0	0	2	0
	Do not know	0	0	1	0
How are your overhead lights controlled (check all that apply)?					
	Switch at wall	0	1	4	0
	Handheld remote	0	0	0	0
	Interface at your computer	0	0	0	0
	Automated system / controlled by building management	0	1	2	0
	Other (please specify)	0	0	1	0
	Do not know / Does not apply	0	0	0	0
To what extent can light levels from your overhead lights be adjusted?					
	Lights turn on and off only	0	0	4	0
	Light level settings are available for high, low, and/or medium	0	0	1	0
	Continuous dimming available	0	1	1	0
Do you notice the brightness of the overhead lights changing automatically?					
	Yes	0	1	0	0
	No	0	0	6	0
	Do not know	0	0	0	0

CCCOE Lighting Survey (Raw Data)

Questions	Answers	Respondents with Other (0)	Respondents with Parabolic (1)	Respondents with Flat lens (6)	Respondents with other (0)
Does the change in brightness bother you?					
	Yes	0	0	0	0
	No	0	1	0	0
	Do not know	0	0	0	0
What type of shading system do you have to control the amount of daylight entering your windows?					
	Manual blinds (e.g., Venetian blinds)	0	1	5	0
	Manual window shades (e.g., roller shades)	0	0	0	0
	Automatic blinds or shades	0	0	0	0
	Other (please specify)	0	0	1	0
	No shading control	0	0	0	0
	I have no daylight in my workspace	0	0	0	0
Can you control the amount of daylight entering your windows without affecting other occupants?					
	Yes	0	1	3	0
	No	0	0	3	0
I am satisfied with my ability to control my overhead lighting.					
	Strongly Disagree	0	0	1	0
	Disagree	0	0	0	0
	Neutral	0	0	4	0
	Agree	0	0	0	0
	Strongly Agree	0	1	1	0
	Does not apply	0	0	0	0
I am satisfied with my ability to control my task lighting.					
	Strongly Disagree	0	0	1	0
	Disagree	0	0	0	0
	Neutral	0	0	1	0
	Agree	0	1	1	0
	Strongly Agree	0	0	1	0
	Does not apply	0	0	2	0
I am satisfied with my ability to control my window shades or blinds.					
	Strongly Disagree	0	0	1	0
	Disagree	0	0	0	0
	Neutral	0	0	1	0
	Agree	0	0	1	0
	Strongly Agree	0	1	2	0
	Does not apply	0	0	1	0
My work surface is evenly lighted without very bright or dim spots.					
	Strongly Disagree	0	0	0	0
	Disagree	0	0	0	0
	Neutral	0	0	1	0
	Agree	0	1	2	0
	Strongly Agree	0	0	2	0
	Does not apply	0	0	0	0
The lights flicker throughout the day.					
	Strongly Disagree	0	1	3	0
	Disagree	0	0	1	0
	Neutral	0	0	0	0
	Agree	0	0	0	0
	Strongly Agree	0	0	0	0
	Does not apply	0	0	2	0
My skin is an unnatural tone under the lighting.					
	Strongly Disagree	0	0	3	0
	Disagree	0	0	0	0
	Neutral	0	1	3	0
	Agree	0	0	0	0
	Strongly Agree	0	0	0	0
	Does not apply	0	0	0	0

CCCOE Lighting Survey (Raw Data)

Questions	Answers	Respondents with Other (0)	Respondents with Parabolic (1)	Respondents with Flat lens (6)	Respondents with other (0)
The lighting fixtures in the general office area around my workspace are nice-looking.					
	Strongly Disagree	0	0	0	0
	Disagree	0	0	0	0
	Neutral	0	0	4	0
	Agree	0	1	0	0
	Strongly Agree	0	0	2	0
	Does not apply	0	0	0	0
The lighting helps create a good image for the organization.					
	Strongly Disagree	0	0	0	0
	Disagree	0	0	0	0
	Neutral	0	1	3	0
	Agree	0	0	1	0
	Strongly Agree	0	0	2	0
	Does not apply	0	0	0	0
The room surfaces (walls, ceilings) have a pleasant brightness.					
	Strongly Disagree	0	0	0	0
	Disagree	0	0	0	0
	Neutral	0	0	4	0
	Agree	0	1	1	0
	Strongly Agree	0	0	1	0
	Does not apply	0	0	0	0
Paper Tasks (reading and writing)					
	Much Too Bright	0	0	0	0
	Too Bright	0	0	0	0
	Just Right	0	1	6	0
	Too Dim	0	0	0	0
	Much Too Dim	0	0	0	0
	Does not apply	0	0	0	0
Reading from a computer screen					
	Much Too Bright	0	0	0	0
	Too Bright	0	0	0	0
	Just Right	0	1	6	0
	Too Dim	0	0	0	0
	Much Too Dim	0	0	0	0
	Does not apply	0	0	0	0
Typing on keyboard					
	Much Too Bright	0	0	0	0
	Too Bright	0	0	0	0
	Just Right	0	1	6	0
	Too Dim	0	0	0	0
	Much Too Dim	0	0	0	0
	Does not apply	0	0	0	0
Filing or locating papers					
	Much Too Bright	0	0	0	0
	Too Bright	0	0	0	0
	Just Right	0	1	6	0
	Too Dim	0	0	0	0
	Much Too Dim	0	0	0	0
	Does not apply	0	0	0	0
Face to face conversations					
	Much Too Bright	0	0	0	0
	Too Bright	0	0	0	0
	Just Right	0	1	6	0
	Too Dim	0	0	0	0
	Much Too Dim	0	0	0	0
	Does not apply	0	0	0	0
Glare reflected from your work surface					
	Always	0	0	0	0
	Often	0	0	0	0
	Sometimes	0	0	2	0
	Rarely	0	1	2	0
	Never	0	0	2	0
Glare from the light fixtures reflected on your computer screen					

CCCOE Lighting Survey (Raw Data)

Questions	Answers	Respondents with Other (0)	Respondents with Parabolic (1)	Respondents with Flat lens (6)	Respondents with other (0)
	Always	0	0	0	0
	Often	0	0	0	0
	Sometimes	0	0	1	0
	Rarely	0	0	1	0
	Never	0	1	4	0
Glare from the window reflected on your computer screen					
	Always	0	0	0	0
	Often	0	0	1	0
	Sometimes	0	0	3	0
	Rarely	0	1	1	0
	Never	0	0	1	0
Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)					
	Always	0	0	0	0
	Often	0	0	0	0
	Sometimes	0	0	1	0
	Rarely	0	0	1	0
	Never	0	1	4	0
Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)					
	Always	0	0	0	0
	Often	0	0	0	0
	Sometimes	0	0	1	0
	Rarely	0	1	0	0
	Never	0	0	5	0
Glare from your task lighting					
	Always	0	0	0	0
	Often	0	0	0	0
	Sometimes	0	0	3	0
	Rarely	0	0	0	0
	Never	0	1	3	0
Direct glare from a window					
	Always	0	0	0	0
	Often	0	0	0	0
	Sometimes	0	0	2	0
	Rarely	0	1	1	0
	Never	0	0	2	0
What is the color appearance of the lighting in your personal workspace?					
	Very Warm	0	0	0	0
	Somewhat Warm	0	0	3	0
	Neutral	0	0	1	0
	Somewhat Cool	0	1	2	0
	Very Cool	0	0	0	0
	Do not know	0	0	0	0
What would you prefer for the color appearance of the lighting in your personal workspace?					
	Very Warm	0	0	0	0
	Somewhat Warm	0	1	1	0
	Neutral	0	0	2	0
	Somewhat Cool	0	0	2	0
	Very Cool	0	0	0	0
	Do not know	0	0	1	0
If you could change the lighting in your office, what would you do? Please check all that apply.					
	Change the location of the overhead lighting fixtures relative to your workstation	0	0	0	0
	Make the overhead lighting fixtures produce more light	0	0	0	0
	Make the overhead lighting fixtures produce less light	0	0	0	0

CCCOE Lighting Survey (Raw Data)

Questions	Answers	Respondents with Other (0)	Respondents with Parabolic (1)	Respondents with Flat lens (6)	Respondents with other (0)
	Make the overhead lighting fixtures less glary	0	0	0	0
	Change the aesthetic appearance of the lighting fixtures	0	0	0	0
	Change the color appearance of the light produced by the lighting fixtures	0	1	0	0
	Add a task light	0	0	0	0
	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	0	0	1	0
	Get better access to a window view	0	0	0	0
	Get better access to daylight	0	0	0	0
	Have light bulbs replaced faster when they burn out and fixtures repaired faster when they break	0	0	0	0
	I would not change anything	0	0	4	0
Please feel free to submit any other comments about your lighting below:					
				The only thing I don't like about these sensor lights is when I am typing at my desk and not moving much, the lights around me go off and it makes the office too dark and gloomy. I have to wave my hands for the lights next to me and walk to next cubicle to activate the lights there.	
Please feel free to submit any other comments about this survey below:					

CCCOE Lighting Survey (User Submissions)

Survey Title	Submission ID	Question ID	Question	Answer	Choice ID	Date Created	Date Survey Submitted
CCCOE Lighting Survey	1023	54	Which of the following best describes the type of work that you do?	Facility management	4	2013-02-11 13:27:32.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	2	What is your age?	Over 50	9	2013-02-11 13:27:35.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	3	What is your gender?	Male	11	2013-02-11 13:27:37.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	4	Which of the following best describes your personal workspace?	Cubicles with partitions below standing eye level	14	2013-02-11 13:28:06.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	5	What type of computer screen do you have?	Traditional Screen (CRT)	18	2013-02-11 13:28:12.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	6	On a typical day, how long are you in your personal workspace?	2-4 hours	21	2013-02-11 13:28:18.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	7	Are you able to see out a window while sitting in your workspace?	Yes	23	2013-02-11 13:28:22.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	8	Do you like the view?	Yes	23	2013-02-11 13:28:25.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	9	Do you sit adjacent to the window?	No	24	2013-02-11 13:28:29.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	10	Which of the following most closely resembles the overhead lighting in your immediate work space?	Fixture 3	88	2013-02-11 13:28:36.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	11	Overall, is the lighting comfortable?	Yes	23	2013-02-11 13:28:40.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	55	Do you have task lighting?	No	24	2013-02-11 13:28:58.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	14	Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.	Uniformly bright walls	32	2013-02-11 13:29:17.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	15	Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:29:32.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	16	Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:29:41.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	17	If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	23	2013-02-11 13:29:48.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	18	Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	Do not know	36	2013-02-11 13:29:57.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	19	How are your overhead lights controlled (check all that apply)?	Switch at wall	37	2013-02-11 13:30:02.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	19	How are your overhead lights controlled (check all that apply)?	New lighting system installed	15	2013-02-11 13:30:49.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	20	To what extent can light levels from your overhead lights be adjusted?	Light level settings are available for high, low, and/or medium	43	2013-02-11 13:30:51.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	56	Do you notice the brightness of the overhead lights changing automatically?	No	24	2013-02-11 13:30:56.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	21	What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	45	2013-02-11 13:31:08.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	22	Can you control the amount of daylight entering your windows without affecting other occupants?	No	24	2013-02-11 13:31:23.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	23	I am satisfied with my ability to control my overhead lighting.	Neutral	52	2013-02-11 13:31:38.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	24	I am satisfied with my ability to control my task lighting.	Neutral	52	2013-02-11 13:31:42.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	25	I am satisfied with my ability to control my window shades or blinds.	Neutral	52	2013-02-11 13:31:48.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	26	My work surface is evenly lighted without very bright or dim spots.	Neutral	52	2013-02-11 13:31:58.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	27	The lights flicker throughout the day.	Strongly Disagree	50	2013-02-11 13:32:06.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	28	My skin is an unnatural tone under the lighting.	Neutral	52	2013-02-11 13:32:10.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	29	The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Agree	54	2013-02-11 13:32:40.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	30	The lighting helps create a good image for the organization.	Strongly Agree	54	2013-02-11 13:32:44.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	31	The room surfaces (walls, ceilings) have a pleasant brightness.	Strongly Agree	54	2013-02-11 13:32:48.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	32	Paper Tasks (reading and writing)	Just Right	57	2013-02-11 13:33:00.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	33	Reading from a computer screen	Just Right	57	2013-02-11 13:33:10.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	34	Typing on keyboard	Just Right	57	2013-02-11 13:33:11.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	35	Filing or locating papers	Just Right	57	2013-02-11 13:33:14.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	36	Face to face conversations	Just Right	57	2013-02-11 13:33:26.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	37	Glare reflected from your work surface	Rarely	61	2013-02-11 13:33:33.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	38	Glare from the light fixtures reflected on your computer screen	Rarely	61	2013-02-11 13:33:36.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	39	Glare from the window reflected on your computer screen	Rarely	61	2013-02-11 13:33:39.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	40	Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Rarely	61	2013-02-11 13:33:44.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	41	Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	60	2013-02-11 13:33:53.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	42	Glare from your task lighting	Sometimes	62	2013-02-11 13:33:58.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	43	Direct glare from a window	Never	60	2013-02-11 13:34:02.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	44	What is the color appearance of the lighting in your personal workspace?	Somewhat Cool	68	2013-02-11 13:34:12.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	45	What would you prefer for the color appearance of the lighting in your personal workspace?	Somewhat Cool	68	2013-02-11 13:34:21.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1023	50	If you could change the lighting in your office, what would you do? Please check all that apply.	I would not change anything	84	2013-02-11 13:34:59.0	2013-02-11 13:35:05.0
CCCOE Lighting Survey	1024	54	Which of the following best describes the type of work that you do?	People management, leadership, and/or training	1	2013-02-11 13:28:09.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	2	What is your age?	Over 50	9	2013-02-11 13:28:11.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	3	What is your gender?	Male	11	2013-02-11 13:28:12.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	4	Which of the following best describes your personal workspace?	Enclosed private office	12	2013-02-11 13:28:16.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	5	What type of computer screen do you have?	Flat Panel Screen	17	2013-02-11 13:28:18.0	2013-02-11 13:32:02.0

CCCOE Lighting Survey (User Submissions)

CCCOE Lighting Survey	1024	6	On a typical day, how long are you in your personal workspace?	4-6 hours	20	2013-02-11 13:28:27.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	7	Are you able to see out a window while sitting in your workspace?	Yes	23	2013-02-11 13:28:29.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	8	Do you like the view?	Yes	23	2013-02-11 13:28:32.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	9	Do you sit adjacent to the window?	Yes	23	2013-02-11 13:28:35.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	10	Which of the following most closely resembles the overhead lighting in your immediate work space?	Fixture 2	87	2013-02-11 13:28:51.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	11	Overall, is the lighting comfortable?	Yes	23	2013-02-11 13:28:54.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	55	Do you have task lighting?	No	24	2013-02-11 13:28:56.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	14	Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.	Uneven light distribution on walls	33	2013-02-11 13:29:08.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	15	Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:29:15.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	16	Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:29:18.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	17	If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	23	2013-02-11 13:29:22.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	18	Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	Yes	23	2013-02-11 13:29:26.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	19	How are your overhead lights controlled (check all that apply)?	Switch at wall	37	2013-02-11 13:29:32.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	19	How are your overhead lights controlled (check all that apply)?	Automated system / controlled by building management	40	2013-02-11 13:29:35.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	20	To what extent can light levels from your overhead lights be adjusted?	Continuous dimming available	44	2013-02-11 13:29:41.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	56	Do you notice the brightness of the overhead lights changing automatically?	Yes	23	2013-02-11 13:29:48.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	57	Does the change in brightness bother you?	No	24	2013-02-11 13:29:51.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	21	What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	45	2013-02-11 13:29:56.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	22	Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	23	2013-02-11 13:29:59.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	23	I am satisfied with my ability to control my overhead lighting.	Strongly Agree	54	2013-02-11 13:30:14.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	24	I am satisfied with my ability to control my task lighting.	Agree	53	2013-02-11 13:30:14.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	25	I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	54	2013-02-11 13:30:18.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	26	My work surface is evenly lighted without very bright or dim spots.	Agree	53	2013-02-11 13:30:25.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	27	The lights flicker throughout the day.	Strongly Disagree	50	2013-02-11 13:30:29.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	28	My skin is an unnatural tone under the lighting.	Neutral	52	2013-02-11 13:30:32.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	29	The lighting fixtures in the general office area around my workspace are nice-looking.	Agree	53	2013-02-11 13:30:37.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	30	The lighting helps create a good image for the organization.	Neutral	52	2013-02-11 13:30:40.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	31	The room surfaces (walls, ceilings) have a pleasant brightness.	Agree	53	2013-02-11 13:30:43.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	32	Paper Tasks (reading and writing)	Just Right	57	2013-02-11 13:30:53.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	33	Reading from a computer screen	Just Right	57	2013-02-11 13:30:54.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	34	Typing on keyboard	Just Right	57	2013-02-11 13:30:55.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	35	Filing or locating papers	Just Right	57	2013-02-11 13:30:55.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	36	Face to face conversations	Just Right	57	2013-02-11 13:30:56.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	37	Glare reflected from your work surface	Rarely	61	2013-02-11 13:31:02.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	38	Glare from the light fixtures reflected on your computer screen	Never	60	2013-02-11 13:31:06.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	39	Glare from the window reflected on your computer screen	Rarely	61	2013-02-11 13:31:10.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	40	Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	60	2013-02-11 13:31:15.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	41	Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Rarely	61	2013-02-11 13:31:19.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	42	Glare from your task lighting	Never	60	2013-02-11 13:31:25.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	43	Direct glare from a window	Rarely	61	2013-02-11 13:31:27.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	44	What is the color appearance of the lighting in your personal workspace?	Somewhat Cool	68	2013-02-11 13:31:33.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	45	What would you prefer for the color appearance of the lighting in your personal workspace?	Somewhat Warm	66	2013-02-11 13:31:38.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1024	50	If you could change the lighting in your office, what would you do? Please check all that apply.	Change the color appearance of the light produced by the lighting fixtures	78	2013-02-11 13:31:49.0	2013-02-11 13:32:02.0
CCCOE Lighting Survey	1025	54	Which of the following best describes the type of work that you do?	Combination of computer work, paper tasks, phone calls and meetings	3	2013-02-11 13:43:43.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	2	What is your age?	31 - 40	7	2013-02-11 13:43:52.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	3	What is your gender?	Female	10	2013-02-11 13:43:55.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	4	Which of the following best describes your personal workspace?	Cubicles with partitions below standing eye level	14	2013-02-11 13:44:13.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	5	What type of computer screen do you have?	Flat Panel Screen	17	2013-02-11 13:44:18.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	6	On a typical day, how long are you in your personal workspace?	More than 6 hours	19	2013-02-11 13:44:23.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	7	Are you able to see out a window while sitting in your workspace?	Yes	23	2013-02-11 13:44:29.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	8	Do you like the view?	Yes	23	2013-02-11 13:44:44.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	9	Do you sit adjacent to the window?	Yes	23	2013-02-11 13:45:11.0	2013-02-11 13:54:54.0

CCCOE Lighting Survey (User Submissions)

CCCOE Lighting Survey	1025	10	Which of the following most closely resembles the overhead lighting in your immediate work space?	Fixture 3	88	2013-02-11 13:45:27.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	11	Overall, is the lighting comfortable?	Yes	23	2013-02-11 13:45:33.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	55	Do you have task lighting?	No	24	2013-02-11 13:45:48.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	14	Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.	Uniformly bright walls	32	2013-02-11 13:47:32.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	15	Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:47:43.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	16	Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:47:52.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	17	If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	23	2013-02-11 13:47:59.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	18	Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	No	24	2013-02-11 13:49:08.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	19	How are your overhead lights controlled (check all that apply)?	Switch at wall	37	2013-02-11 13:49:38.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	20	To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	42	2013-02-11 13:49:57.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	56	Do you notice the brightness of the overhead lights changing automatically?	No	24	2013-02-11 13:50:10.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	21	What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	45	2013-02-11 13:50:19.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	22	Can you control the amount of daylight entering your windows without affecting other occupants?	No	24	2013-02-11 13:50:36.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	23	I am satisfied with my ability to control my overhead lighting.	Strongly Agree	54	2013-02-11 13:50:43.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	24	I am satisfied with my ability to control my task lighting.	Does not apply	31	2013-02-11 13:50:47.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	25	I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	54	2013-02-11 13:50:51.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	27	The lights flicker throughout the day.	Strongly Disagree	50	2013-02-11 13:51:11.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	28	My skin is an unnatural tone under the lighting.	Strongly Disagree	50	2013-02-11 13:51:51.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	29	The lighting fixtures in the general office area around my workspace are nice-looking.	Neutral	52	2013-02-11 13:52:15.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	31	The room surfaces (walls, ceilings) have a pleasant brightness.	Neutral	52	2013-02-11 13:52:30.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	30	The lighting helps create a good image for the organization.	Neutral	52	2013-02-11 13:52:31.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	32	Paper Tasks (reading and writing)	Just Right	57	2013-02-11 13:52:40.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	33	Reading from a computer screen	Just Right	57	2013-02-11 13:52:44.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	34	Typing on keyboard	Just Right	57	2013-02-11 13:52:46.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	35	Filing or locating papers	Just Right	57	2013-02-11 13:52:47.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	36	Face to face conversations	Just Right	57	2013-02-11 13:52:49.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	37	Glare reflected from your work surface	Sometimes	62	2013-02-11 13:53:05.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	38	Glare from the light fixtures reflected on your computer screen	Never	60	2013-02-11 13:53:24.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	39	Glare from the window reflected on your computer screen	Sometimes	62	2013-02-11 13:53:27.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	40	Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	60	2013-02-11 13:53:40.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	41	Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	60	2013-02-11 13:53:45.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	42	Glare from your task lighting	Never	60	2013-02-11 13:53:48.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	43	Direct glare from a window	Rarely	61	2013-02-11 13:53:55.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	44	What is the color appearance of the lighting in your personal workspace?	Neutral	67	2013-02-11 13:54:14.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	45	What would you prefer for the color appearance of the lighting in your personal workspace?	Neutral	67	2013-02-11 13:54:15.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1025	50	If you could change the lighting in your office, what would you do? Please check all that apply.	I would not change anything	84	2013-02-11 13:54:28.0	2013-02-11 13:54:54.0
CCCOE Lighting Survey	1026	54	Which of the following best describes the type of work that you do?	Combination of computer work, paper tasks, phone calls and meetings	3	2013-02-11 13:46:58.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	2	What is your age?	Over 50	9	2013-02-11 13:47:01.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	3	What is your gender?	Female	10	2013-02-11 13:47:06.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	4	Which of the following best describes your personal workspace?	Cubicles with partitions above standing eye level	13	2013-02-11 13:47:17.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	5	What type of computer screen do you have?	Flat Panel Screen	17	2013-02-11 13:47:24.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	6	On a typical day, how long are you in your personal workspace?	More than 6 hours	19	2013-02-11 13:47:31.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	7	Are you able to see out a window while sitting in your workspace?	Yes	23	2013-02-11 13:47:36.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	8	Do you like the view?	Yes	23	2013-02-11 13:47:39.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	9	Do you sit adjacent to the window?	Yes	23	2013-02-11 13:47:44.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	10	Which of the following most closely resembles the overhead lighting in your immediate work space?	Fixture 3	88	2013-02-11 13:49:32.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	11	Overall, is the lighting comfortable?	Yes	23	2013-02-11 13:49:35.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	55	Do you have task lighting?	Yes	23	2013-02-11 13:49:41.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	12	Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Undercabinet task light	26	2013-02-11 13:49:47.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	13	What type of control do you have for your task lighting?	On/Off switch	29	2013-02-11 13:49:53.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	14	Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.	Do not know	36	2013-02-11 13:50:30.0	2013-02-11 13:57:55.0

CCCOE Lighting Survey (User Submissions)

CCCOE Lighting Survey	1026	15	Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:50:50.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	16	Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:50:59.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	17	If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	23	2013-02-11 13:51:09.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	18	Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	Yes	23	2013-02-11 13:51:22.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	19	How are your overhead lights controlled (check all that apply)?	Automated system / controlled by building management	40	2013-02-11 13:52:08.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	20	To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	42	2013-02-11 13:52:38.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	56	Do you notice the brightness of the overhead lights changing automatically?	No	24	2013-02-11 13:52:43.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	21	What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	45	2013-02-11 13:52:59.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	22	Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	23	2013-02-11 13:53:06.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	23	I am satisfied with my ability to control my overhead lighting.	Strongly Disagree	50	2013-02-11 13:53:16.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	24	I am satisfied with my ability to control my task lighting.	Strongly Disagree	50	2013-02-11 13:53:17.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	25	I am satisfied with my ability to control my window shades or blinds.	Strongly Disagree	50	2013-02-11 13:53:19.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	26	My work surface is evenly lighted without very bright or dim spots.	Strongly Agree	54	2013-02-11 13:53:51.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	27	The lights flicker throughout the day.	Strongly Disagree	50	2013-02-11 13:53:54.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	28	My skin is an unnatural tone under the lighting.	Strongly Disagree	50	2013-02-11 13:54:18.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	29	The lighting fixtures in the general office area around my workspace are nice-looking.	Strongly Agree	54	2013-02-11 13:54:34.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	30	The lighting helps create a good image for the organization.	Strongly Agree	54	2013-02-11 13:54:40.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	31	The room surfaces (walls, ceilings) have a pleasant brightness.	Neutral	52	2013-02-11 13:54:46.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	32	Paper Tasks (reading and writing)	Just Right	57	2013-02-11 13:55:04.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	33	Reading from a computer screen	Just Right	57	2013-02-11 13:55:11.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	34	Typing on keyboard	Just Right	57	2013-02-11 13:55:13.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	35	Filing or locating papers	Just Right	57	2013-02-11 13:55:15.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	36	Face to face conversations	Just Right	57	2013-02-11 13:55:19.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	37	Glare reflected from your work surface	Never	60	2013-02-11 13:55:53.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	38	Glare from the light fixtures reflected on your computer screen	Never	60	2013-02-11 13:55:35.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	39	Glare from the window reflected on your computer screen	Sometimes	62	2013-02-11 13:55:48.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	40	Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	60	2013-02-11 13:56:01.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	41	Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	60	2013-02-11 13:56:06.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	42	Glare from your task lighting	Never	60	2013-02-11 13:56:11.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	43	Direct glare from a window	Sometimes	62	2013-02-11 13:56:20.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	44	What is the color appearance of the lighting in your personal workspace?	Somewhat Cool	68	2013-02-11 13:56:54.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	45	What would you prefer for the color appearance of the lighting in your personal workspace?	Somewhat Cool	68	2013-02-11 13:57:05.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1026	50	If you could change the lighting in your office, what would you do? Please check all that apply.	Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	80	2013-02-11 13:57:34.0	2013-02-11 13:57:55.0
CCCOE Lighting Survey	1027	54	Which of the following best describes the type of work that you do?	Combination of computer work, paper tasks, phone calls and meetings	3	2013-02-11 13:55:36.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	2	What is your age?	Over 50	9	2013-02-11 13:55:39.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	3	What is your gender?	Female	10	2013-02-11 13:55:40.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	4	Which of the following best describes your personal workspace?	Cubicles with partitions below standing eye level	14	2013-02-11 13:56:01.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	5	What type of computer screen do you have?	Flat Panel Screen	17	2013-02-11 13:56:05.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	6	On a typical day, how long are you in your personal workspace?	More than 6 hours	19	2013-02-11 13:56:10.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	7	Are you able to see out a window while sitting in your workspace?	Yes	23	2013-02-11 13:56:14.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	8	Do you like the view?	Yes	23	2013-02-11 13:56:17.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	9	Do you sit adjacent to the window?	Yes	23	2013-02-11 13:56:21.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	10	Which of the following most closely resembles the overhead lighting in your immediate work space?	Fixture 3	88	2013-02-11 13:56:41.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	11	Overall, is the lighting comfortable?	Yes	23	2013-02-11 13:56:45.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	55	Do you have task lighting?	Yes	23	2013-02-11 13:56:48.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	12	Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Desktop task light	27	2013-02-11 13:56:56.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	13	What type of control do you have for your task lighting?	on/off with variation	15	2013-02-11 13:57:19.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	14	Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.	Uniformly bright walls	32	2013-02-11 13:57:36.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	15	Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	23	2013-02-11 13:57:44.0	2013-02-11 14:01:28.0

CCCOE Lighting Survey (User Submissions)

CCCOE Lighting Survey	1027	16	Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	No	24	2013-02-11 13:57:48.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	18	Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	No	24	2013-02-11 13:57:56.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	19	How are your overhead lights controlled (check all that apply)?	Switch at wall	37	2013-02-11 13:58:03.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	20	To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	42	2013-02-11 13:58:14.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	56	Do you notice the brightness of the overhead lights changing automatically?	No	24	2013-02-11 13:58:20.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	21	What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	45	2013-02-11 13:58:28.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	22	Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	23	2013-02-11 13:58:33.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	23	I am satisfied with my ability to control my overhead lighting.	Neutral	52	2013-02-11 13:58:40.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	24	I am satisfied with my ability to control my task lighting.	Agree	53	2013-02-11 13:59:12.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	25	I am satisfied with my ability to control my window shades or blinds.	Agree	53	2013-02-11 13:59:16.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	26	My work surface is evenly lighted without very bright or dim spots.	Agree	53	2013-02-11 13:59:23.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	27	The lights flicker throughout the day.	Disagree	51	2013-02-11 13:59:26.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	28	My skin is an unnatural tone under the lighting.	Neutral	52	2013-02-11 13:59:33.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	29	The lighting fixtures in the general office area around my workspace are nice-looking.	Neutral	52	2013-02-11 13:59:47.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	30	The lighting helps create a good image for the organization.	Neutral	52	2013-02-11 13:59:53.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	31	The room surfaces (walls, ceilings) have a pleasant brightness.	Neutral	52	2013-02-11 13:59:54.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	32	Paper Tasks (reading and writing)	Just Right	57	2013-02-11 14:00:03.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	33	Reading from a computer screen	Just Right	57	2013-02-11 14:00:05.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	34	Typing on keyboard	Just Right	57	2013-02-11 14:00:07.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	35	Filing or locating papers	Just Right	57	2013-02-11 14:00:08.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	36	Face to face conversations	Just Right	57	2013-02-11 14:00:10.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	37	Glare reflected from your work surface	Sometimes	62	2013-02-11 14:00:15.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	38	Glare from the light fixtures reflected on your computer screen	Sometimes	62	2013-02-11 14:00:18.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	39	Glare from the window reflected on your computer screen	Sometimes	62	2013-02-11 14:00:20.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	40	Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Sometimes	62	2013-02-11 14:00:29.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	41	Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Sometimes	62	2013-02-11 14:00:49.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	42	Glare from your task lighting	Sometimes	62	2013-02-11 14:00:50.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	43	Direct glare from a window	Sometimes	62	2013-02-11 14:00:52.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	44	What is the color appearance of the lighting in your personal workspace?	Somewhat Warm	66	2013-02-11 14:01:02.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1027	45	What would you prefer for the color appearance of the lighting in your personal workspace?	Somewhat Warm	66	2013-02-11 14:01:07.0	2013-02-11 14:01:28.0
CCCOE Lighting Survey	1028	54	Which of the following best describes the type of work that you do?	Combination of computer work, paper tasks, phone calls and meetings	3	2013-02-12 10:37:31.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	2	What is your age?	Over 50	9	2013-02-12 10:37:35.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	3	What is your gender?	Female	10	2013-02-12 10:37:36.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	4	Which of the following best describes your personal workspace?	Cubicles with partitions below standing eye level	14	2013-02-12 10:37:48.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	5	What type of computer screen do you have?	BOTH CRT AND FLAT PANEL	15	2013-02-12 10:38:10.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	6	On a typical day, how long are you in your personal workspace?	More than 6 hours	19	2013-02-12 10:38:14.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	7	Are you able to see out a window while sitting in your workspace?	No	24	2013-02-12 10:38:22.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	11	Overall, is the lighting comfortable?	Yes	23	2013-02-12 10:38:37.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	14	Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.	Uniformly bright walls	32	2013-02-12 10:39:03.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	10	Which of the following most closely resembles the overhead lighting in your immediate work space?	Fixture 3	88	2013-02-12 10:40:03.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	15	Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	23	2013-02-12 10:40:25.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	16	Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	23	2013-02-12 10:40:32.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	17	If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	23	2013-02-12 10:41:03.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	18	Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	Yes	23	2013-02-12 10:41:09.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	19	How are your overhead lights controlled (check all that apply)?	Automated system / controlled by building management	40	2013-02-12 10:41:19.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	20	To what extent can light levels from your overhead lights be adjusted?	Continuous dimming available	44	2013-02-12 10:41:39.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	56	Do you notice the brightness of the overhead lights changing automatically?	No	24	2013-02-12 10:41:42.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	21	What type of shading system do you have to control the amount of daylight entering your windows?	COVERING CONTROLS IN ANOTHER AREA NEAR MY WORK SPACE	15	2013-02-12 10:42:24.0	2013-02-12 10:45:50.0

CCCOE Lighting Survey (User Submissions)

CCCOE Lighting Survey	1028	22	Can you control the amount of daylight entering your windows without affecting other occupants?	No	24	2013-02-12 10:42:31.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	23	I am satisfied with my ability to control my overhead lighting.	Neutral	52	2013-02-12 10:42:51.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	24	I am satisfied with my ability to control my task lighting.	Does not apply	31	2013-02-12 10:42:54.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	25	I am satisfied with my ability to control my window shades or blinds.	Does not apply	31	2013-02-12 10:43:00.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	26	My work surface is evenly lighted without very bright or dim spots.	Agree	53	2013-02-12 10:43:10.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	27	The lights flicker throughout the day.	Does not apply	31	2013-02-12 10:43:16.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	28	My skin is an unnatural tone under the lighting.	Neutral	52	2013-02-12 10:43:21.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	29	The lighting fixtures in the general office area around my workspace are nice-looking.	Neutral	52	2013-02-12 10:43:28.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	30	The lighting helps create a good image for the organization.	Agree	53	2013-02-12 10:43:32.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	31	The room surfaces (walls, ceilings) have a pleasant brightness.	Agree	53	2013-02-12 10:43:36.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	32	Paper Tasks (reading and writing)	Just Right	57	2013-02-12 10:43:44.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	33	Reading from a computer screen	Just Right	57	2013-02-12 10:43:45.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	34	Typing on keyboard	Just Right	57	2013-02-12 10:43:47.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	35	Filing or locating papers	Just Right	57	2013-02-12 10:43:49.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	36	Face to face conversations	Just Right	57	2013-02-12 10:43:51.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	37	Glare reflected from your work surface	Never	60	2013-02-12 10:43:57.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	38	Glare from the light fixtures reflected on your computer screen	Never	60	2013-02-12 10:43:58.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	39	Glare from the window reflected on your computer screen	Never	60	2013-02-12 10:44:01.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	40	Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	60	2013-02-12 10:44:07.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	41	Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	60	2013-02-12 10:44:10.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	42	Glare from your task lighting	Never	60	2013-02-12 10:44:12.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	43	Direct glare from a window	Never	60	2013-02-12 10:44:14.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	44	What is the color appearance of the lighting in your personal workspace?	Somewhat Warm	66	2013-02-12 10:44:34.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	45	What would you prefer for the color appearance of the lighting in your personal workspace?	Do not know	36	2013-02-12 10:44:52.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	50	If you could change the lighting in your office, what would you do? Please check all that apply.	I would not change anything	84	2013-02-12 10:45:18.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1028	51	Please feel free to submit any other comments about your lighting below:	Love the way our lighting system works.	85	2013-02-12 10:45:50.0	2013-02-12 10:45:50.0
CCCOE Lighting Survey	1029	54	Which of the following best describes the type of work that you do?	Facility management	4	2013-02-12 15:16:05.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	2	What is your age?	Over 50	9	2013-02-12 15:16:08.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	3	What is your gender?	Female	10	2013-02-12 15:16:10.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	4	Which of the following best describes your personal workspace?	Cubicles with partitions below standing eye level	14	2013-02-12 15:16:37.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	5	What type of computer screen do you have?	Flat Panel Screen	17	2013-02-12 15:16:41.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	6	On a typical day, how long are you in your personal workspace?	More than 6 hours	19	2013-02-12 15:16:49.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	7	Are you able to see out a window while sitting in your workspace?	No	24	2013-02-12 15:16:58.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	10	Which of the following most closely resembles the overhead lighting in your immediate work space?	Fixture 3	88	2013-02-12 15:17:57.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	11	Overall, is the lighting comfortable?	Yes	23	2013-02-12 15:18:02.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	55	Do you have task lighting?	Yes	23	2013-02-12 15:18:05.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	12	Which of the following types of lighting fixtures most closely resembles the task lighting in your personal workspace?	Undercabinet task light	26	2013-02-12 15:18:12.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	13	What type of control do you have for your task lighting?	On/Off switch	29	2013-02-12 15:18:16.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	14	Which of the following most closely resembles the lighting on the walls or partitions in your immediate office area.	Uneven light distribution on walls	33	2013-02-12 15:18:44.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	15	Do the overhead lighting fixtures in your workspace turn on automatically (when you enter the space, on a set schedule, or both)?	Yes	23	2013-02-12 15:18:56.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	16	Do the overhead lighting fixtures in your workspace turn off automatically (when you leave the space, on a set schedule, or both)?	Yes	23	2013-02-12 15:19:08.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	17	If your lights turn off automatically, can you turn them back on from your immediate work area?	Yes	23	2013-02-12 15:19:23.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	18	Can you control the overhead lights in your personal workspace without changing the lights in neighboring areas?	Yes	23	2013-02-12 15:20:16.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	19	How are your overhead lights controlled (check all that apply)?	Switch at wall	37	2013-02-12 15:20:22.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	20	To what extent can light levels from your overhead lights be adjusted?	Lights turn on and off only	42	2013-02-12 15:20:39.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	56	Do you notice the brightness of the overhead lights changing automatically?	No	24	2013-02-12 15:21:07.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	21	What type of shading system do you have to control the amount of daylight entering your windows?	Manual blinds (e.g., Venetian blinds)	45	2013-02-12 15:21:15.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	22	Can you control the amount of daylight entering your windows without affecting other occupants?	Yes	23	2013-02-12 15:21:18.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	23	I am satisfied with my ability to control my overhead lighting.	Neutral	52	2013-02-12 15:22:01.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	24	I am satisfied with my ability to control my task lighting.	Strongly Agree	54	2013-02-12 15:22:10.0	2013-02-12 15:30:51.0

CCCOE Lighting Survey (User Submissions)

CCCOE Lighting Survey	1029	25	I am satisfied with my ability to control my window shades or blinds.	Strongly Agree	54	2013-02-12 15:22:14.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	26	My work surface is evenly lighted without very bright or dim spots.	Strongly Agree	54	2013-02-12 15:22:45.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	27	The lights flicker throughout the day.	Does not apply	31	2013-02-12 15:22:50.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	28	My skin is an unnatural tone under the lighting.	Strongly Disagree	50	2013-02-12 15:23:10.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	29	The lighting fixtures in the general office area around my workspace are nice-looking.	Neutral	52	2013-02-12 15:23:32.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	30	The lighting helps create a good image for the organization.	Neutral	52	2013-02-12 15:23:42.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	31	The room surfaces (walls, ceilings) have a pleasant brightness.	Neutral	52	2013-02-12 15:23:53.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	32	Paper Tasks (reading and writing)	Just Right	57	2013-02-12 15:24:09.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	33	Reading from a computer screen	Just Right	57	2013-02-12 15:24:11.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	34	Typing on keyboard	Just Right	57	2013-02-12 15:24:14.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	35	Filing or locating papers	Just Right	57	2013-02-12 15:24:18.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	36	Face to face conversations	Just Right	57	2013-02-12 15:24:19.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	37	Glare reflected from your work surface	Rarely	61	2013-02-12 15:25:00.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	39	Glare from the window reflected on your computer screen	Often	63	2013-02-12 15:25:14.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	38	Glare from the light fixtures reflected on your computer screen	Never	60	2013-02-12 15:26:05.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	40	Glare from the overhead lighting in your immediate workspace (usually experienced as discomfort)	Never	60	2013-02-12 15:26:24.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	41	Direct glare from the light fixtures beyond your immediate workspace (the light fixtures appear too bright)	Never	60	2013-02-12 15:26:35.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	42	Glare from your task lighting	Sometimes	62	2013-02-12 15:27:07.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	44	What is the color appearance of the lighting in your personal workspace?	Somewhat Warm	66	2013-02-12 15:27:36.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	45	What would you prefer for the color appearance of the lighting in your personal workspace?	Neutral	67	2013-02-12 15:27:57.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	50	If you could change the lighting in your office, what would you do? Please check all that apply.	I would not change anything	84	2013-02-12 15:29:18.0	2013-02-12 15:30:51.0
CCCOE Lighting Survey	1029	51	Please feel free to submit any other comments about your lighting below:	The only thing I don't like about these sensor lights is when I am typing at my desk and not moving much, the lights around me go off and it makes the office too dark and gloomy. I have to wave my hands for the lights next to me and walk to next cubicle to activate the lights there.	85	2013-02-12 15:30:51.0	2013-02-12 15:30:51.0

CCCOE PG&E ETD Advanced Lighting Control Project

Installer Survey

Installer: Positive Energy, Basil Goodrich supervisor

M&V: Emcor Energy Services

1. Have you previously installed fixture retrofits that incorporate controls similar to the controls used at this installation? _X_Yes __No

2. Compared to installing fixture retrofits without dedicated controls, this installation was:

_X_ **Simpler** than installing fixture retrofits without dedicated controls.
__ **About the same** as installing fixture retrofits without dedicated controls.
__ **Slightly more difficult** than installing fixture retrofits without dedicated controls.
__ **Significantly more difficult** than installing fixture retrofits without dedicated controls.

3. Did any situational elements **unrelated** to the technology (such as access, wiring, etc.) increase the difficulty of this installation relative to a "normal" installation? _X_Yes __No

Please describe.

This system requires a server that be installed in the data or electrical closet

4. Did any situational elements **related** to the technology increase the difficulty of this installation relative to a "normal" installation? __Yes _X_No

Please describe.

All fixtures were the same and all fixtures were retrofitted with the same H/W

5. Did the controls come with accurate installation and programming instructions? _X_Yes __No

6. Were the replacement (dimming) ballasts received in good physical condition/working order?

_X_Yes __No

But two ballasts failed after installation after evoking dimming for a few weeks. They flickered when dimmed too deeply

Describe any missing/broken/incomplete elements and how the manufacturer responded or reconciled, if applicable.

None.

7. Were the controls received in good physical condition/working order? _X_Yes __No

Describe any missing/broken/incomplete elements and how the manufacturer responded or reconciled, if applicable.

Compatible battery backup ballasts needed to be sourced (Bodine B-100's). Enlighted and CCCOE sourced these ballasts.

8. Please provide additional comments as applicable:

The fixtures were retrofitted from 4 lamp T8's to 2 lamp T8's in 2006. The fixtures required much cleaning for dust, etc.

Installer Survey Addendum for CCCOE ETD – Commissioning

Design Phase

Design was simplified by every fixture having an identical integrated occupancy, ambient and temperature sensor. This allowed us to just use the Reflected Ceiling Plan to count the fixtures and know their layout. We did not need to determine where to put the ambient sensor for day lighting or occupancy sensors like systems that require specific placement of the sensors. Thus every fixture gets the same hardware.

Tuning, Savings and Environmental expectations

Meet with facilities management to discuss tuning strategies and any potential issues with employees or specific areas or space types. We got a copy of the floor plan of the spacer we were to control. We load that floor plan on our Universal Interface so that we can map the light fixtures to the floor plan for tuning. We discussed operating hours and occupancy patterns. After this customer meeting the facilities manager bought in to the savings plan and strategies.

Commissioning Phase

In order to attain maximum savings it is recommended to commission the system in a few phases in order not to "startle" the occupants. Change in the building environment needs to be gradual. Commissioning can occur over a few periods say two weeks. Here is the example of CCCOE: Day one: add a level of task tuning to reduce the fixture energy by 10%. Then a week later reduce the fixture wattage to 20% down. Add occupancy and ambient sensing a few days later but use conservative timeouts so lights take longer to go to dim and even longer to go to off. Next continue the process of tuning the system more aggressively. If the complaints are not widespread put the few or one folk(s) complaining into a special profile for them selves and continue reducing the wattage around that person by tweaking the saving strategies. It will become apparent when there is enough feedback that the system is tuned to the lowest level for the occupants in that area.

Occupant Feedback

Multiple CCCOE occupants under the controlled lights gave many positive responses to the system. They liked the light level. They liked saving energy as a group. They appreciated the lights dimming to reduce energy because it was less noticeable than just turning off. There were a couple that wanted their lights brighter. We tuned those employees' lights slightly higher than the others

APPENDIX H. ANALYSIS OF SYSTEM DATA

The analysis of system data is in the file EES_Enlighted data comp.xlsx.