INTRODUCTION

The largest single load in commercial buildings, typically consuming 40% of electric energy, is fluorescent electric lighting. Despite improvements in equipment efficiency, lighting energy is squandered because it is not managed effectively. According to the Lawrence Berkeley Laboratory (http://eetd.lbl.gov/btd/papers/46009.pdf), previous research indicates that lighting controls using occupancy sensors, photosensors, and light scheduling to reduce lighting of unoccupied spaces can lower lighting energy consumption by at least 35% compared to an already efficient electronic ballast system.

Besides cost, another problem that improved lighting controls help to solve is the lack of individual control over fluorescent light ballasts. Normally, a single light switch is the only mechanism available to control lights in an office or room. If the office is a multipurpose room or has several work areas, occupants have very little control over the lighting in their work area. Lighting controls offer building occupants a way to have some control over their environment. According to the Lawrence Berkeley Laboratory, tastes in light level, tolerance for glare, and so forth differ between individuals by as much as 1500 lux or more. General overhead lighting in buildings often consists of 3-lamp fluorescent fixtures that create relatively uniform illumination of 500-800 lux everywhere, with little room for adjustments. Control of ambient light intensity and color balance can be particularly important in CAD workstation environments.

The problems of cost and control demonstrate a need for a cost-effective and robust choice for developing a lighting control system. An excellent choice for developing a lighting control system, when renovating or in new building designs, is a 1-Wire® system. It can help solve both cost issues and the lack of individual ballast control. A lighting control system can be implemented using primarily DS2890 1-Wire digital potentiometers, along with dimming fluorescent electronic ballasts. The 1-Wire bus provides the multidrop-networking scheme. The DS2890s provide a digital address, in effect, for each electronic ballast (and of course, the potentiometer dimming ability), and the dimming ballast provides the interface for the actual dimming function. This document describes an example lighting control system based on a 1-Wire network with DS2890 digital potentiometers.

OVERVIEW

The concept of controlling fluorescent lighting through a 1-Wire network is shown in Figure 1. The basic interconnect scheme here consists of a 1-Wire master, a 1-Wire network of DS2890s, and electronic dimming light ballasts. This setup allows for advanced control of lighting, and for automated light control scheduling as well. How advanced the lighting control system is depends upon the capabilities of the 1-Wire master.

The 1-Wire master can be a computer workstation, a TINI (please see http://www.ibutton.com/TINI for more information), or a microcontroller. The 1-Wire master is responsible for communicating to the 1-Wire devices residing on the 1-Wire network. For instance, the 1-Wire master can send signals to increase

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or decrease the resistance on a specific DS2890 digital potentiometer connected to a specific dimming ballast, thus, brightening or dimming the fluorescent lights connected to that ballast. Or, at other times, the 1-Wire master may be called upon to read the resistance level (digital wiper position), to determine the current brightness of a light ballast.

Each DS2890 gives the respective fluorescent light ballast it is connected to, in effect, a digital address. This address is made up of a 64-bit, guaranteed-unique number, called a 1-Wire network address. The DS2890 also provides 256 separate resistance wiper positions which, in turn, enables 256 brightness settings per ballast.

LIGHTING CONTROL OVERVIEW Figure 1
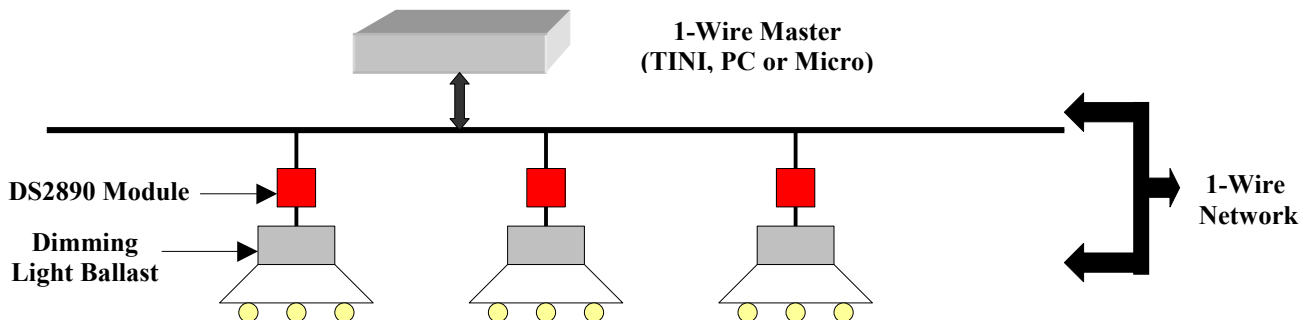
HARDWARE
For basic lighting control functionality with DS2890s, the following is a list of suggested hardware.

1) **1-Wire Master**. The 1-Wire master can be a computer workstation, a microcontroller, or a TINI[®]. Multiple 1-Wire masters can provide more flexibility and extensibility as large buildings can be subdivided into different lighting areas such as individual rooms or floors. Each lighting area with its own 1-Wire network can then be assigned to a 1-Wire master. A good candidate for this is the 1-Wire master called TINI. TINIs are inexpensive and have ethernet connectivity built-in, so that each TINI and potentially each light ballast can be controlled through the internet. A sample implementation of just this sort has been successfully achieved. A description is available from the following website: http://www.ibutton.com/TINI/applications/weblights. This website also provides computer program source code that can control a 1-Wire network of DS2890s connected to dimming fluorescent lights through the internet. The code can be run on a TINI or a PC.

2) **Dimming Ballasts**. The fluorescent light fixtures being interfaced to must contain dimming ballasts. Several manufacturers offer dimming electronic ballasts for fluorescent lighting. Internally, Maxim/Dallas Semiconductor has installed several dimming ballasts made by Universal Lighting Technologies (Magnetek). For single bulb control, the B132R120V5 Ballastar electronic dimming ballast (http://www.universalballast.com/productLines/ap_sheets/ELFB/B132R120V5.pdf) was installed. For two bulbs, the B232SR120V5 Ballastar electronic dimming ballast (http://www.universalballast.com/productLines/ap_sheets/ELFB/B232SR120V5.pdf) was installed. Each dimming electronic ballast has two wires, usually purple and gray, in addition to the 120-VAC power connections. The purple and gray wires (see Figure 2) are for low voltage (nominally 0 to 10V DC) brightness control. When these wires are left open, the fixture goes to full brightness. When these wires are shorted together, the fixture goes to about 5% brightness with the units mentioned above.

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Many makers of electronic ballasts now make 0V to 10V dimming electronic ballasts. Here are a few of them:

- Advance Transformer – Mark VII series of dimming ballasts http://www.advancetransformer.com/literature/pdf/EL-2010-R02.pdf.
- Philips – HF REGULATOR (for 240 V European systems and 1-10V dimming) http://www.eur.lighting.philips.com/products/Catalog/7/7062/7062s.pdf
- Osram Sylvania – Quicktronic series http://www.sylvania.com/bin/gotocatalog.scr
- Prescolite – Intelectplus (for 120, 208, 240, and 277 volt systems) http://www.prescolite.com
- Lutron – Fluorescent Dimming Ballasts TVE series http://www.lutron.com/ballast/BallastGuide/BallastGuide.pdf
- Universal Lighting Technologies (formerly, Magnetek) – Ballastar series http://www.universalballast.com/productLines/ballast/fl_dimm.html

3) **DS2890s**. Specifically, every light ballast should be connected to its own DS2890. The datasheet for the DS2890 can be found at http://pdfserv.maxim-ic.com/arpdf/DS2890.pdf. The DS2890 is a digital potentiometer and permits 256 intermediate brightness levels under 1-Wire control through its 256 resistance wiper settings. Most dimming electronic ballasts control brightness levels from 5% to 100% by allowing an external device such as the DS2890 to change the voltage applied across the dimming ballast's control wires over a 0V to 10V range. Once every dimming ballast has been interfaced to a DS2890, the DS2890s can then be connected together to form a 1-Wire network. The 1-Wire network is then connected to the 1-Wire master. If the 1-Wire master ever gets disconnected from the 1-Wire Network or if the 1-Wire Network gets shorted, the ballasts revert to 100% brightness under manual control at the local light switch.

SIMPLE DS2890 CONNECTION SCHEMATIC Figure 2
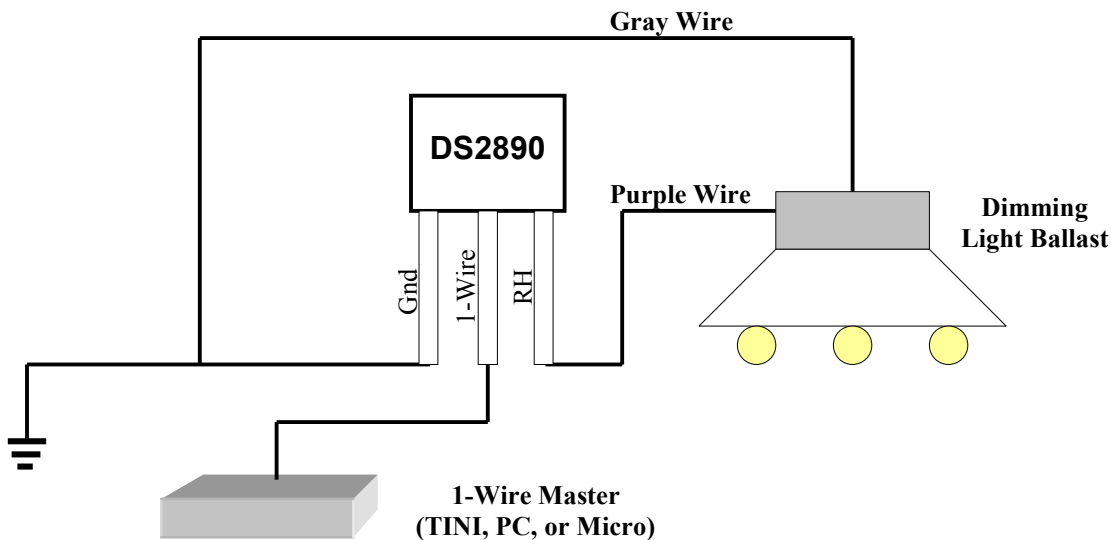
ADVANCED LIGHTING CONTROLS

The above 1-Wire Network is very extensible. Not only can it encompass a network of DS2890 digital potentiometers but it can also include temperature sensors, analog-to-digital converters (ADCs), and digital switches (just to name a few). With these devices, along with an internet-enabled 1-Wire master, a more advanced lighting control network can be built. One component of advanced lighting controls is the on/off switch. The above-mentioned scheme allows for light dimming with DS2890s, but not necessarily for on and off functionality. The DS2406 digital switch (http://pdfserv.maxim-ic.com/arpdf/DS2406.pdf) can be used to accommodate this functionality.

Motion sensors can be used as advanced lighting controls. A motion sensor's output can be monitored on a 1-Wire network, also through a DS2406 digital switch operating as a digital input. If no motion is detected in a room for a certain period of time, the 1-Wire master can send the signal to the on/off switch to turn off the lights in the unoccupied room.

Light balancing with photosensors also should be considered when implementing advanced lighting controls. Photosensors can be located in rooms with windows such that when the sensors detect certain amounts of external light, the light intensity of the fluorescent lights in the room can be lowered, thus allowing for further cost savings. The light detection can be achieved through the use of a 1-Wire ADC, such as a DS2450 (http://pdfserv.maxim-ic.com/arpdf/DS2450.pdf) connected to a photosensing LED or photocell. Another light balancing technique is to open and close motorized blinds at different times of the day to maximize lighting and minimize electricity usage. These could also be controlled through the use of DS2406 digital switches.

Finally, light scheduling for buildings or groups of buildings can save energy and cut costs. If a 1-Wire master, such as a PC or a TINI is connected to the ethernet and thus, to a corporate network or the internet, a server can control them and their remote 1-Wire networks. This enables scheduling of different lighting events for different times of the day or for weekends or holidays. For example, at night and on weekends, all lighting could be turned off throughout an entire complex, except for those rooms with occupants. The computer server running the light scheduling software could communicate with each 1-Wire master giving specific scheduling actions to perform periodically. Obviously, this has great potential for cost savings throughout a building.

CONCLUSION

In conclusion, fluorescent lighting controls can easily be implemented through a 1-Wire network of DS2890s, a 1-Wire master, and dimming fluorescent light ballasts. As an added benefit, individual ballast control can be attained, giving lighting intensity and/or color balance choices to the building occupant. Not only can significant cost-savings be achieved through fluorescent light dimming, but also through more advanced controls providing motion sensing, light balancing, and light scheduling. Since the 1-Wire network is highly extensible, as new light-saving technologies are developed, there is a high probability that they can also be interfaced to a 1-Wire network. This makes a 1-Wire lighting system worth the investment.