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Analog and Digital Fluorescent Lighting Dimming Systems

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I. INTRODUCTION

Digitally addressable lighting is slowly emerging as a popular means for controlling complete lighting environments for a wide variety of different applications. Individual control of each lamp enables the end user to precisely deliver the correct amount of light when and where it is required. Managing the light in this manner allows for a massive reduction in global energy consumption due to lighting. Industrial environments can conserve the total energy required for lighting while actually increasing light quality in certain areas at given times to maximize employee productivity. The focus of this paper is on digital control of fluorescent lighting using a standard interface. Analog dimming is presented to give an overview of other dimming systems as well.

II. ANALOG DIMMING

Analog dimming applications include office lighting, conference rooms, concert halls and museums. The functions performed by analog dimming electronic ballasts include electromagnetic interference (EMI) filtering to block ballast generated noise, rectification, power factor correction (PFC) for sinusoidal input current, dimming ballast control with driver and timing for high-frequency operation, an isolated 1-to-10VDC analog interface for dimming, and final ballast output stage to power the lamp (Figure 1). This analog solution accepts a 1-to-10VDC control voltage for setting the

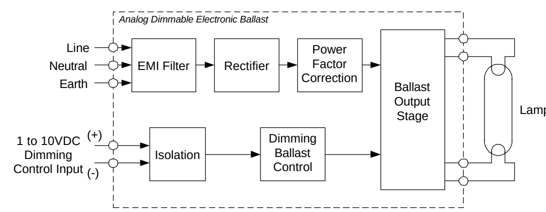

Figure 1: Analog dimmable ballast block diagram

dimming level and has been standardized in Europe for many years. Several ballast companies exist which currently market these type of dimmable ballasts.

A typical solution on the market includes a custom ASIC for performing the dimming control functions (Figure 2). The 1-to-10VDC dimming control input signal is galvanically isolated with a transformer and then serves as the lamp current reference for the ASIC. The lamp current is usually sensed and fed back to the ASIC as well. The error between the reference and feedback is then used to steer the frequency of the resonant-mode ballast output stage in the correct direction such that the lamp current matches the reference and the desired lamp brightness setting is achieved. 1 volt at the control input represents minimum lamp brightness and 10 volts represents maximum lamp brightness. This approach requires three ICs that include a power factor controller IC, an ASIC, and a driver IC for the output stage

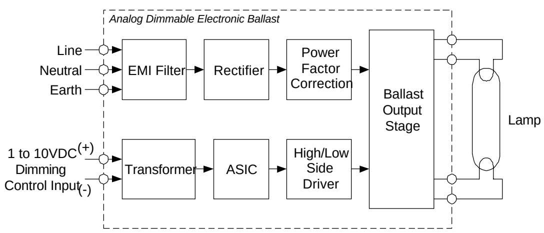

Figure 2, Typical analog dimming ASIC solution

A standard approach exists on the market which uses the IR2159 Dimming Ballast IC (Figure 3). In this solution, the number of ICs is reduced to two as the dimming control and driver circuitry for the output stage are combined in a single IC

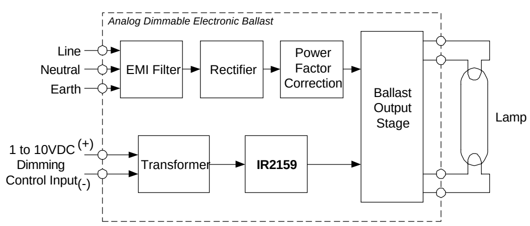

Figure 3, Analog dimming solution using the IR2159 Dimming IC

A complete 1-to-10VDC dimming system includes several analog dimming ballasts connected in parallel and controlled simultaneously from a single dimming control unit (Figure 4). This type of configuration is used in, for example, conference rooms where it is convenient to dim the entire room up or down from a single wall-mounted control unit.

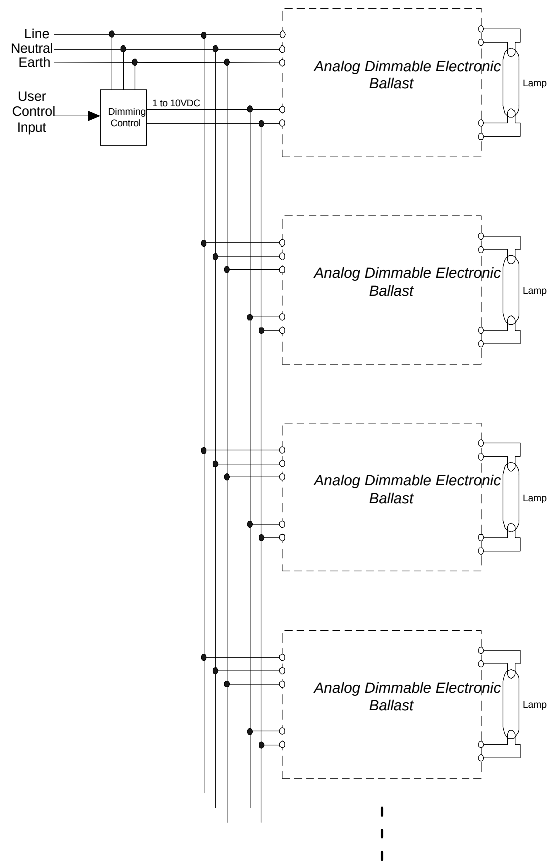

Figure 4, Typical 1-10V dimming system

Higher-end dimming systems also exist which provide constant light throughout the day. In these type of systems, the lamp brightness is measured in different locations of a large room and converted into a voltage using photocells (Figure 5). This voltage is then fed back to a control unit and compared against a pre-set reference. The resulting error between the two is then used to adjust the 1-to-10VDC input of each dimming ballast such that a constant brightness is maintained.

In applications where there is a mixture of external light and fluorescent lighting, the system will self-dim up or down continuously throughout the day to keep the brightness constant. This is a useful feature in environments such as an office with windows or a museum with skylights. If the sun goes behind a cloud, for example, then the system will dim the lamps up to maintain constant light in the room. Also, to compensate for higher levels of external light near the windows, more light will be generated from the lamps which are located further away from the windows such that the light gradient across a given room is constant.

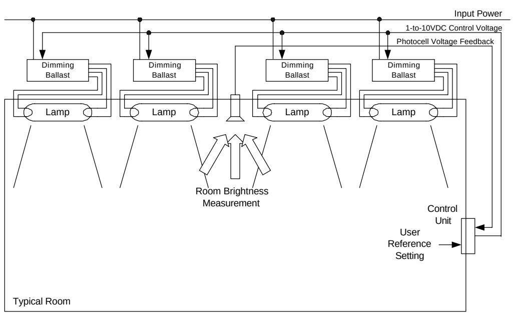

Figure 5, Self-dimming constant-light system

III DIGITAL DIMMING

A digital dimming ballast includes an EMI filter, rectifier, power factor correction and ballast output stage (Figure 6). The digital ballast also includes a micro-controller for sending and receiving information digitally. The micro-controller functions include storing the ballast address, receiving user instructions, setting the dim reference for the ballast control, receiving status information from the ballast control and sending status information back to the user. This allows for complete and precise control of an entire lighting environment

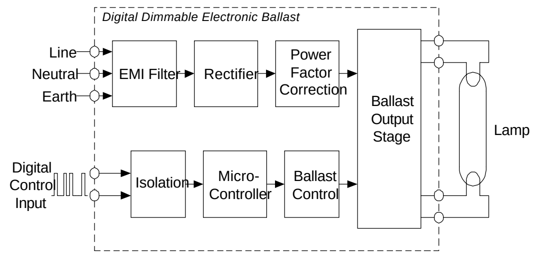

Figure 6, Digital dimming ballast block diagram

A typical digital dimming solution includes an ASIC for sending and receiving instructions from the micro-controller and an optocoupler for isolating the control input (Figure 7). The ASIC contains the necessary functions for controlling the lamp brightness as well as a digital interface for communicating with the micro-controller. This approach requires four primary ICs which include a power factor controller IC, a micro-controller IC, an ASIC and a driver IC for the output stage

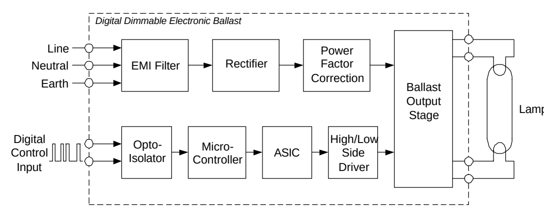

Figure 7, Typical digital dimming ASIC solution

A standard solution also exists that includes the IR2159 Dimming IC (Figure 8). With this approach the total number of ICs has been reduced to three as the IR2159 also includes the driver circuitry for the ballast output stage.

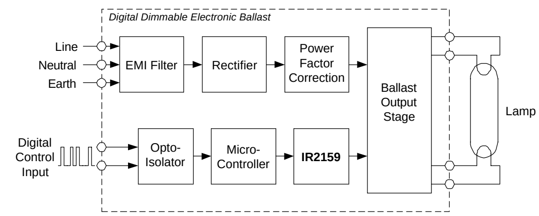

Figure 8, Digital dimming solution using the IR2159 dimming IC

A complete digital dimming system includes the dimming ballasts and a digital control unit for converting information from an Ethernet connection to the communication protocol required by the micro-controller of each ballast (Figure 9). Applications for this system include building management or studio lighting where it is desired to control single or groups of lamps for conserving energy, performing lamp maintenance or creating precision lighting effects

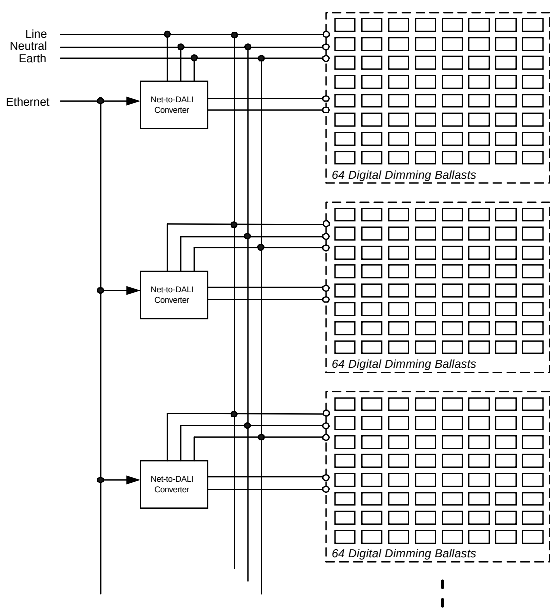

Figure 9, Typical digital dimming system

IV. THE DALI

A system known as the Digitally Addressable Lighting Interface (DALI), an addition to the existing electronic ballast performance Standard IEC929, exists in Europe which has been widely adopted by several companies and is in the process of becoming a standard. This is a two-wire system with a defined digital communication protocol for sending and receiving instructions. The DALI includes a bitstream definition for both a forward and backward going messages (Figure 10).

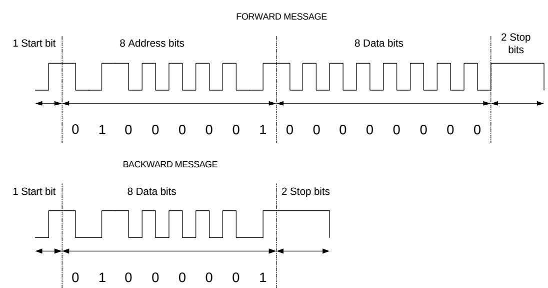

Figure 10, DALI protocol bitstream definition

The forward message includes a start bit, 8 address bits, 8 data bits and 2 stop bits. The 8 address bits allows for communication with all of the ballasts at once, groups of ballasts (16 maximum) or individual ballasts (64 maximum). The functions performed by the 8 data bits of the forward or backward message have been summarized in a table (Table 1), and include such features as on/off, dim level and fade time.

Set or Query	Power Commands
Actual Dim Level	Turn On
Power On Level	Turn Off
System Failure Level	Dim Up
Minimum Level	Dim Down
Maximum Level	Step Up
Fade Rate	Step Down
Fade Time	Recall Max
Change Address	Recall Min
Change Group	Go To Scene
Scene Light Level	
Physical Minimum Level	
Status	

Table 1, DALI data bits functions summary

The DALI provides 256 levels of brightness between the minimum and maximum dim levels and also includes a logarithmic dimming curve (Figure 11). This gives larger increments in brightness at high dim levels and smaller increments at low dim levels. The result is a dimming curve which appears more linear to the human eye.

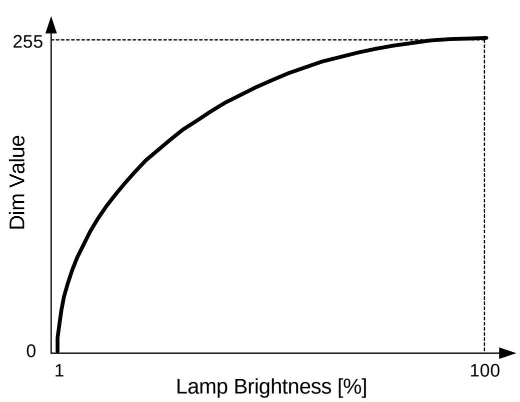

Figure 11, DALI logarithmic dimming curve with 256 brightness levels

V. SOFTWARE-CONTROLLABLE LIGHT

A fully-functional digitally addressable dimming ballast was designed, built and tested for performance. The input stage was designed for high power factor and low harmonic distortion using a generic PFC IC. The IR2159 Dimming Ballast IC was used to provide smooth dimming control of the lamp. The IR2159 also includes a 0-to-5V analog dimming input which is convenient for interfacing to a micro-controller. The Microchip Technology PIC16F628 micro-controller was used for the digital control section. The PIC16F628 acts as an interface between the IR2159 ballast controller and the DALI. Data is transmitted to the ballast from the DALI and the PIC16F628 collects the data through an isolation circuit. The PIC16F628 then interprets the data and sends the appropriate signals to the IR2159 if necessary or sends information back to the DALI. The PIC16F628 also performs lamp fault detection and disables the IR2159 if a lamp fault is present.

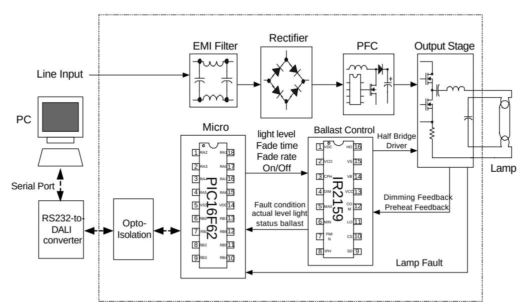

Figure 12, IRPLDIM2 digitally addressable dimming ballast

Software was written for controlling the ballast from a PC. The software has a graphical user interface for performing all of the DALI functions (Figure 13). The PC sends commands via a serial cable to a RS232-to-DALI converter which then communicates with the ballast via a two-wire connection.

Figure 13, Graphical user interface of the digital dimming software

The ballast and software system successfully performed all DALI functions while giving high-performance dimming as well. Temperature, lifetime, performance margins, packaging, layout, manufacturability and cost were all considered during the design process.

VI. CONCLUSIONS

An overview has been presented covering both analog and digital dimming systems. An existing digital interface has been used as an example of what functions are possible with a complete digital system. A DALI-compatible reference design has also been shown which allows for complete software control of a fluorescent lamp.