Digitally Addressable DALI Dimming Ballast

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Abstract: ***A digitally addressable digital dimming ballast has been developed. It conforms to DALI standard requiring very few parts and operates at very low power. Applications 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 prefect light quality. The design includes the digital dimming ballast, the code of the micro-controller and a platform to control the ballast by PC.***

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.

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 in each ballast (Figure 1).

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.

II. DIGITAL DIMMING

Digital dimming ballasts include an EMI filter, rectifier, power factor correction, and ballast output stage (Figure 2). 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.

A typical digital dimming solution includes an ASIC for sending and receiving instructions from the micro-controller and optocouplers for isolating the control input (Figure 3). The ASIC contains the necessary functions for controlling the lamp brightness as well as a digital interface for communicating with the micro-controller.

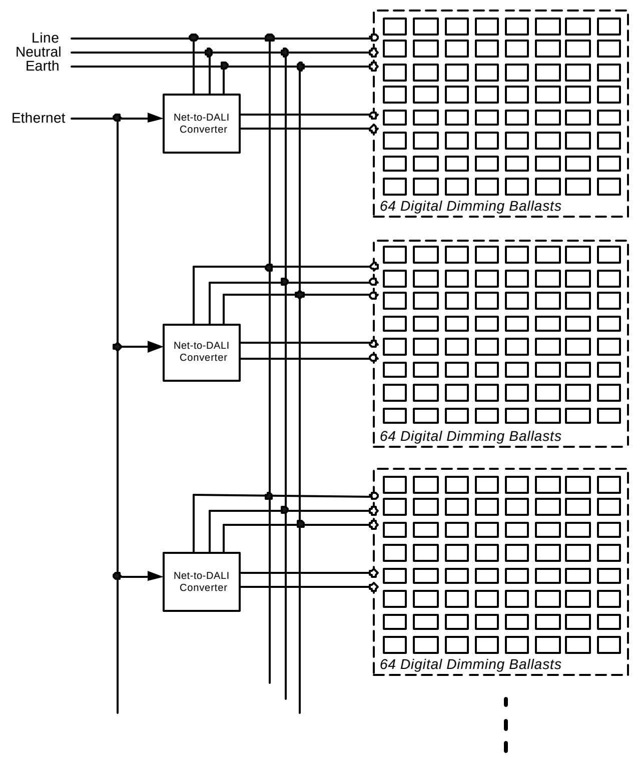


Figure 1, Typical digital dimming system.

International IOR Rectifier

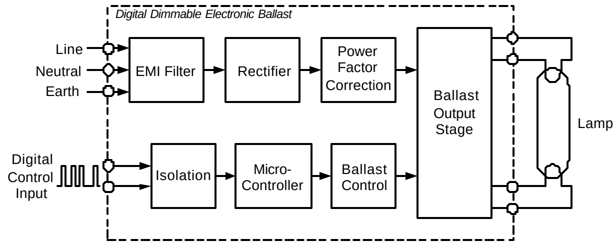


Figure 2, Digital dimming ballast block diagram.

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.

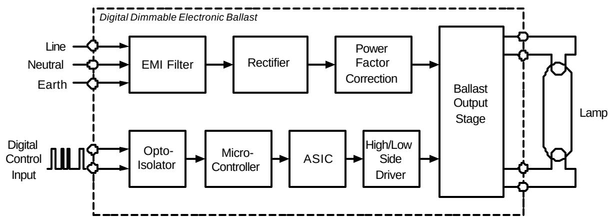


Figure 3, Typical digital dimming ASIC solution.

A standard solution also exists that includes the IR2159 Dimming IC (Figure 4). 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.

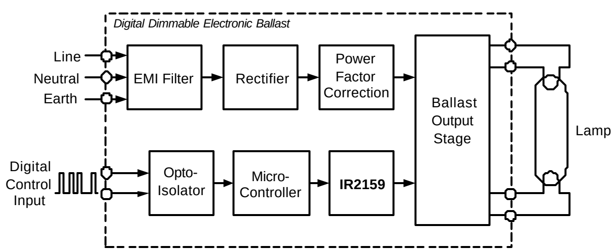


Figure 4, Digital dimming solution using the IR2159 Dimming IC.

III. DALI

A system known as the Digitally Addressable Lighting Interface (DALI) 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 forward and backward going messages (standard prlEC929).

The DALI allows for communication with all of the ballasts at once, groups of ballasts (16 maximum) or individual ballasts (64 maximum). The functions performed include on/off, dim level and fade time. Various operating parameters can be changed and stored dynamically within the ballast memory. For example, scene levels can be set for different groups of ballasts. Also, maximum brightness, minimum brightness, power-on light level and failure light level and several other features can be set as desired. Another feature is the ability to diagnose problems such as lamp failures.

The DALI provides 256 levels of brightness between the minimum and maximum dim levels and also includes a logarithmic dimming curve (Figure 5). 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 linear to the human eye.

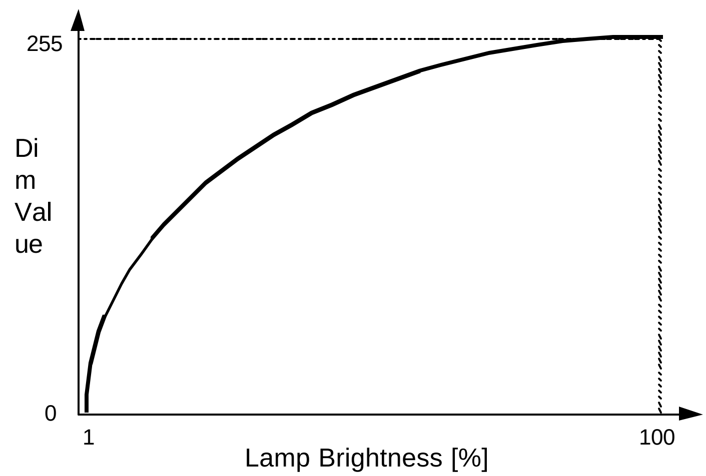


Figure 5, DALI logarithmic dimming curve with 256 brightness levels

IV. IRPLDIM2 REFERENCE DESIGN KIT

IR and Microchip Jointly developed a solution for digitally addressable digital dimming ballasts. It conforms to DALI standard. A fully-functional digitally addressable dimming ballast was designed (Figure 6), built and tested for performance.

Figure 6, IRPLDIM2: Digitally Addressable DALI Dimming Ballast

This reference design is a high efficiency, high power factor, digital dimming electronic ballast designed to drive a rapid start fluorescent lamp. The design contains an active power factor correction circuit for universal voltage input as well as a ballast control circuit using the IR2159. The design also includes a PIC16F628 micro-controller and an isolation circuit for connecting to a Digitally Addressable Lighting Interface (DALI). Other features include EMI filtering, transient protection and lamp fault protection (Figure 8).

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 (phase control method, patented by IR). The IR2159 also includes a 0-to-5V analog dimming input, which is convenient for interfacing to a micro-controller. The 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.

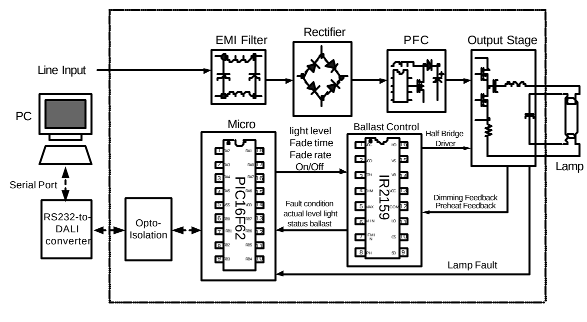


Figure 8, IRPLDIM2 Digitally Addressable Dimming Ballast.

The main advantages of this solution are:

1) Low component count (only 92 components!)
2) Low power, low power standby due to an innovative Shut-down and communication method (this makes it possible to get 5V from the bus without an additional input)
3) Fast and easy design for customers adopting this solution (modifying the code for the micro and changing the ballast section with the new Ballast Designer software)

Some others features are:

- Interface DALI (2 wires)
- High Power Factor/ Low THD
- High Frequency Operation
- Programmable Lamp Filament Preheating
- Programmable Ignition
- High precision Digital Dimming
- Logarithmic Dimming
- Diagnostic and fault control
- Lamp Fault Protection
- Brownout Protection
- Phase control dimming
- Optically Isolated Communications

This is a good example of merging digital technology (innovative software tricks) with high voltage analog technology (innovative hardware tricks) to face the modern market issue of energy saving, reducing complexity and cost and with an user-friendly design-development kit to reduce the design time for the customers adopting this solution.

V. CONTROL BALLAST IC/ MICRO-CONTROLLER

The communication between the micro-controller and the IR2159 is done with four signals (Figure 9). These signals are used for digital dimming (RB3), turning the ballast on or off (RB4), and fault detection (RB5 & RB6). The micro-controller controls the IR2159 by the following 3 pins: pin SD for shutdown of the IC (active high), pin FMIN used for fault detection (0 if the IC is in fault mode) and pin DIM to control the brightness. The micro-controller receives lamp information by the signal Lamp-out, connected to the lamp.

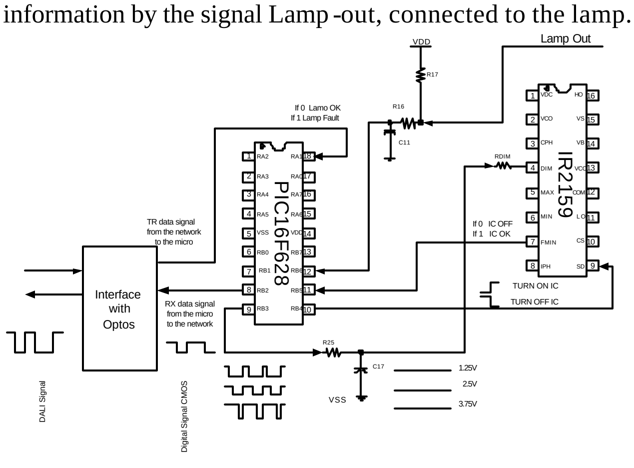


Figure 9, *Micro-controller/IR2159 Communication*

The shutdown signal (RB4) enables or disables the IR2159. When high, the lamp is off and the IR2159 is disabled with minimal current flowing. When low, the lamp is on. The PIC16F628 has control of this line and determines if lamp should be on or off based on fault conditions and user requested settings from the DALI. There are two signals used for fault detection, lamp-out (RB6), and fault (RB5). The lamp-out signal indicates the presence of a lamp or lamp fault. When the lamp is removed the lamp-out signal is pulled up to VDD by the pull-up resistor R17 and the software forces the IR2159 to shutdown. When the lamp is changed, this pin goes to 0 Volts, the micro-controller turns the IR2159 on again and the lamp re-starts automatically. Other fault conditions are indicated by the fault signal (pin FMIN of the IR2159). A low on the fault signal indicates that the IR2159 is in a fault state (the IR2159 turns off automatically in fault conditions such us VCC fault, over-current, failure to strike or low AC line and will remain in this FAULT state until the IC is reset.

The IR2159 requires a 0.5-volt to 5-volt analog voltage (in pin DIM) to perform dimming, thus 0.5 volts corresponds to the 1% arc power level and 5 volts corresponds to the 100% arc power level. The PIC16F628 provides a pulse width modulated signal on pin RB3 that is filtered with a single RC network (R25 and C17). This provides an analog voltage for dimming. The micro can change the dim voltage from 0.5V to 5V by changing the duty cycle and therefore generate 256 different voltage levels for the IR2159. To conform to the digital dimming requirements, the output is logarithmic rather than linear. Since the human eye is much more sensitive to lower light levels than high levels, the logarithmic output appears to be linear. Therefore the PIC16F628 is programmed to produce a logarithmic voltage and the IR2159 drives the lamp arc power (Figure 10).

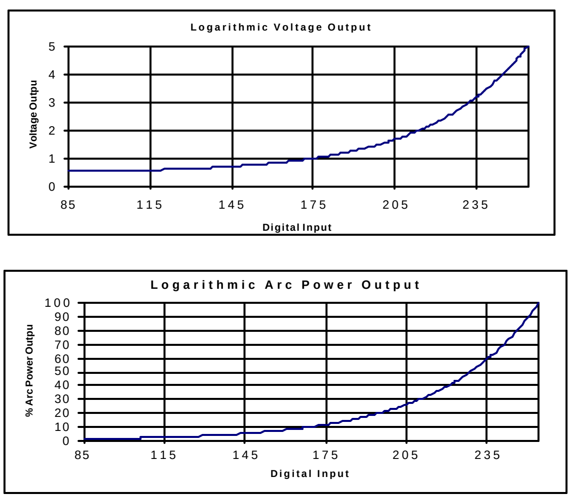


Figure 10, Dimming Characteristics.

The micro-controller can also change the fade time by controlling the speed in which the duty cycle changes.

The relation between light level and dim level can be tuned according to specific needs. The minimum light level can be changed by adjusting RMIN, and the maximum level can be changed adjusting RMAX. RMIN sets the lower phase boundary corresponding to minimum lamp power when VDIM = 0.5V, and RMAX sets the upper phase boundary corresponding to maximum lamp power when VDIM = 5V. RMAX must be set after RMIN.

VI. DALI INTERFACE/MICRO-CONTROLLER

The Digitally Addressable Lighting Interface is optically isolated from the micro-controller. Figure 11 shows the connections between DALI and micro-controller.

The two wires from the DALI are converted to four signals. Two of the four are the transmit signal (RB2) and receive signal (RX_DALI). The other two signals are the communications-enable (RB0) signal and the receive-drive (RB1) signal. The transmit signal and the receive signal directly correlate to the levels seen on the Digitally Addressable Lighting Interface. For receiving higher voltage logic on the DALI is translated to 5 volt logic at the micro-controller, and for transmission, the 5 volt logic is translated to the higher voltage logic on the DALI.

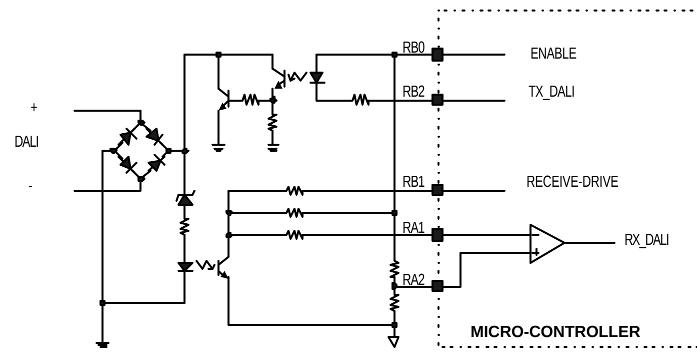


Figure 11, DALI/ Micro-controller communication.

The ballast achieves very low power by controlling the communications circuit with the communication-enable signal and the receive-drive signal. During normal operation the PIC16F628 enables the communication circuitry with the communication-enable signal. With this signal there is enough current, less than 100uA, to indicate when data is being sent to the ballast, but not enough current to accurately transfer the data. Upon detection (done by a S/H built into the PIC16F628) the receive-drive is asserted to raise the current above 500uA to achieve good signal transfer across the isolation. The receive-drive signal is only enabled long enough to transfer all the data; then it is disabled (waveforms in Figure 12). This method strongly reduces the power/current use. The comparator built into the PIC16F628 is used to set the threshold for detection of the incoming data. The signal RA2 is used as threshold for the comparator.

With shutdown there are some unique power conditions. With the shutdown line low and the lamp ignited, the PIC16F628 derives its power from the charge pump of the IR2159. The charge pump provides enough current for the micro-controller to run at its internal frequency of 4MHz during normal operation. When the shutdown line is asserted the IR2159 is disabled, and the charge pump is no longer functioning. Current is drawn directly from the high voltage DC line through a high value resistor. The micro-controller is put to sleep during this time to minimize current draw and power dissipation. To receive data, which requires significant current, the PIC16F628 wakes up and starts the charge pump of the IR2159 long enough to process the command, typically less than 25ms, but not long enough to ignite the lamp (waveforms in Figure 12). Doing this unique management minimizes power dissipation during shutdown.

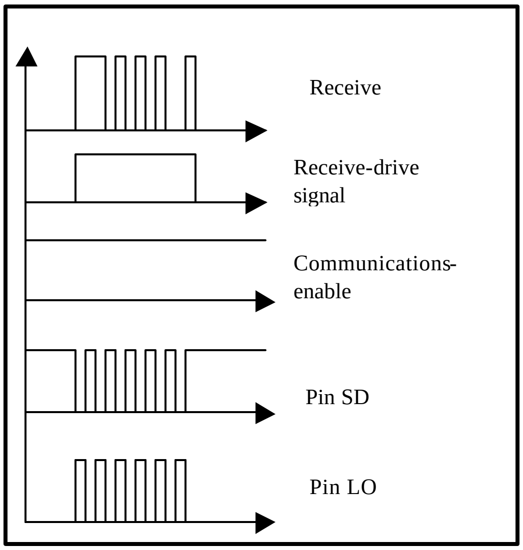


Figure 13, Communication Signals between micro-controller/DALI

VII. REFERENCE DESIGN KIT TOOLS

The Reference Design Kit (Figure 14) consists of these following items:

1. IRPLDIM2 - DALI Ballast
2. RS232-DALI Bridge
3. DALI CD with software and design information

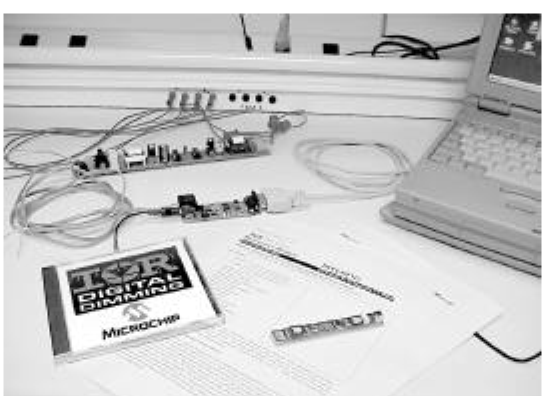


Figure 14, Reference Design Kit Setup.

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 15). 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.

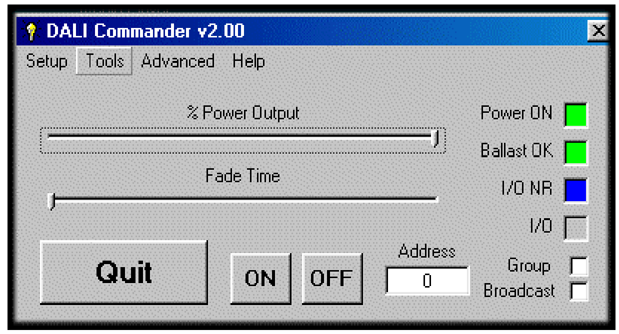


Figure 15, Graphical user interface of the digital dimming software.

The ballast and software system successfully performed all DALI functions while giving high-performance dimming as well.

The CD encloses: Layout files, BOM and schematics, AN, Users manual, micro-controller code and software to drive the ballast by PC.

To adapt the ballast to different lamp types and configurations you can use the BDA software on our WEB (www.irf.com) that will give you the new BOM, schematic and Layout files when selecting the kind of lamp, the number of lamps and the lamp configuration (Figure 16).

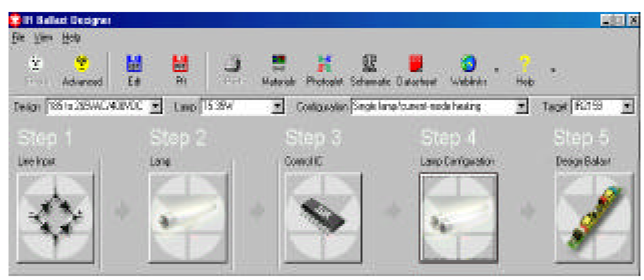


Figure 16, Graphical user interface of the BDA software.

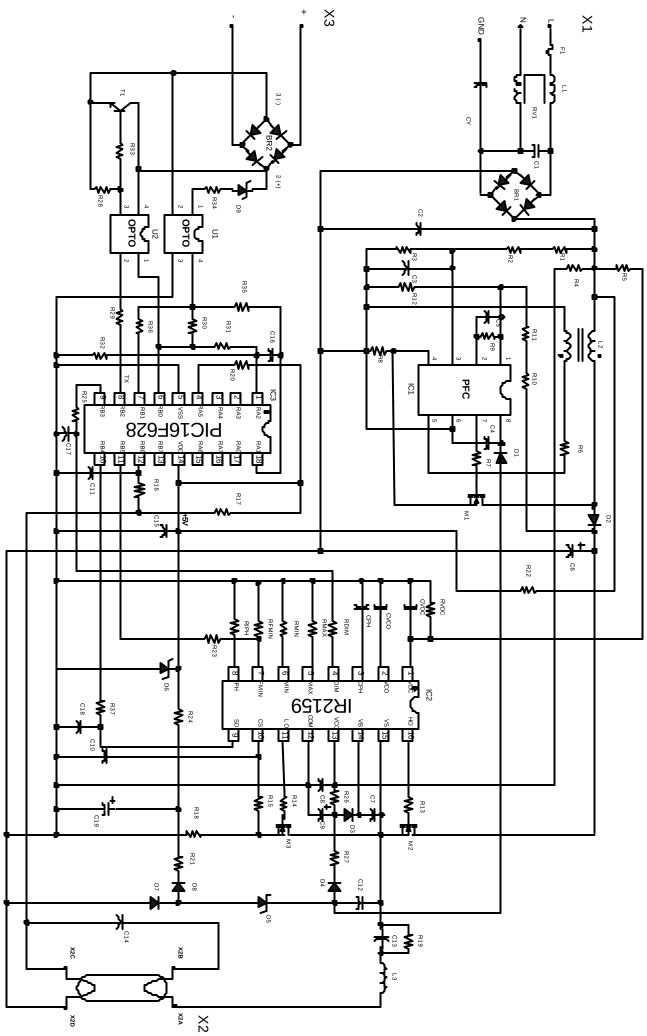
VI. CONCLUSIONS

A digitally addressable digital dimming ballast has been developed which conforms to the DALI standard. This reference design (IRPLDIM2) is a high efficiency, high power factor, digital dimming electronic ballast designed to drive rapid start fluorescent lamps. Some features are:

1) Low component count (only 92!)

2) Low power, due to an innovative communications and Shut-down method
3) Fast and easy design for customers adopting this solution (modifying the code for the micro and adapting the ballast section with the new BDA software)

APPENDIX i: Schematics



APPENDIX ii: BOM

IRPLDIM2E **Bill of Materials**

Lamp Type: T8/36W, Line Input Voltage: 185 to 265 VAC

Reference	Description
BR1	Bridge Rectifier, 1A, 1000V
C4, C5, CPH, CVDC	Capacitor, 0.47uF, SMT 1206
C3	Capacitor, 0.01uF, SMT 1206
C1	Capacitor, 0.33uF, 275VAC
C2, C13	Capacitor, 0.1uF, 400VDC
C7, C8, C11, C18	Capacitor, 0.1uF, SMT1206
C15	Capacitor, 0.22uF, SMT1206
C6	Capacitor, 10uF, 450VDC,105C
C9	Capacitor, 4.7uF, 25VDC, 105C
C19	Capacitor, 10uF, 25VDC, 105C
C10	Capacitor, 220pF, SMT 1206
C16	Capacitor, 1nF, SMT 1206
C12	Capacitor, 1nF, 1KV, SMT 1812
C14	Capacitor, 10nF, 1600VDC
CVCO	Capacitor, 47nF, SMT 1206
C17	Capacitor, 1uF, SMT 1206
CY	Y-Capacitor
D4, D7	Diode, 1N4148, SMT DL35
D1, D8	Diode, 1N4148
D2, D3	Diode, 1A 600V SMB
D5	12 V Zener SMT
D9	5.1 V Zener SMT
D6	5.6V Zener SMT
L1	EMI Inductor, 1x10mH, 0.7A
L2	PFC Inductor, 2.0mH, 2.0Apk
L3	Inductor, 2.0mH, 2.0Apk
M1, M2, M3	Transistor Mosfet
R15	Resistor, 1K Ohm, SMT 1206
R33	Resistor, 470 Ohm, SMT 1206
RFMIN	Resistor, 39K Ohm, SMT 1206
RDIM, R12, R20, R35, R36	Resistor, 10K Ohm, SMT 1206
RIPH	Resistor, 18K Ohm, SMT 1206
R34	Resistor, 5.1K Ohm, SMT 1206
RVDC	Resistor, 27K Ohm, SMT 1206
RMIN	Resistor, 28K Ohm, SMT 1206
RMAX	Resistor, 32.4K Ohm,SMT1206
R1, R2	Resistor, 680KOhm, SMT 1206
R3	Resistor, 7.5K Ohm, SMT 1206
R6	Resistor, 22K Ohm, SMT1206

R7, R13, R14, R21, R24	Resistor, 22 Ohm, SMT 1206
R9, R16, R30	Resistor, 100KOhm, SMT 1206
R10, R11	Resistor, 820KOhm, SMT 1206
R17	Resistor, 1M Ohm, SMT1206
R8	Resistor, 1 Ohm, ¼ Watt
R18	Resistor, 0.68 Ohm, ¼ Watt
R19	Resistor, 100K Ohm, ¼ Watt
R4	Resistor, 470 K Ohm
R5	Resistor, 1M Ohm
R26, R27	Resistor, 10 Ohm, SMT1206
R22	Resistor, 270 K Ohm, 0.5W
R23	Resistor, 470 KOhm, SMT1206
R31	Resistor, 360KOhm, SMT1206
R28	Resistor, 4.7 KOhm, SMT 1206
R29	Resistor, 2.2 KOhm, SMT 1206
R32	Resistor, 75K, SMT 1206
R25, R37	Resistor, 47 KOhm, SMT1206
F1	Resistor, 0.5 Ohm, ½ Watt
IC1	PFC IC for PWR FACTOR
IC2	IC, Dimming Ballast Controller
U1, U2	Mini-flat package Photo coupler
U3	Micro-controller PDIP
T1	SOT23 MP Transistor NPN
BR2	.5A 200V Mini SM Bridge Rect
X1	Connector, 2 terminal
X2	Connector, 4 terminal
X3	Phone Connector RJ11
J1, J2, J3, J4, J5, J6, J7	Jumper
R01, R02, R03, R04, R05, R06, R07, R08	Resistor, 0 Ohm, SMT 1206