AP3983 (PSR Switcher) + AL1794 (4-Channel Linear CCR LED Driver) 3-Channel Warm Dimming (WD) / 3-Channel Tunable Color (TC) Smart Connected Light Bulb (SCL) Reference Design

GENERAL DESCRIPTION

The emerging Smart Connected Light (SCL) Bulbs, as Internet Of Things (IoT) devices in Smart Home environment, are characterized by integration of wireless-connectivity microcontroller (MCU) in LED light bulbs. Users can manage LED light bulbs through smart phone APPs to achieve the following needs:

- Energy saving (through dimming of brightness) - 1-channel Dimmable White (1-ch DW)
- Light quality management – 2-channel Tunable White (2-ch TW)
- Entertainment lighting – 3-channel Tunable Color (3-ch TC) or 4-channel White+RGB (4-ch W+RGB)

Typical functional block diagram of SCL bulbs consists of:

- AC-DC Power Conversion
- LED Driver
- Emitter Module
- Wireless MCU Connectivity

This application note describes the complete reference design of a 6.5W PAR16 ZigBee-Enabled 3-channel Warm Dimming (WD) and Tunable Color (TC) SCL bulbs for both commercial and residential lighting applications. It serves as a good starting point for system designers to further customize SCL bulb design to their desired performance and cost consideration for similar products.

KEY SPECIFICATION

- Model_#1: P16-DD-LE-LO-LD-3WD
  Model_#2: P16-DD-LE-LO-LD-3TC
- Lamp Shape: PAR16
- Operating Power: 6.5W
- Operating Voltage: 100V-240V
- Frequency: 50/60Hz
- Average Lifetime: 25,000Hrs
- Bulb Base: E26/E27
- Lumen: > 250 lumens
- CCT Range:
  Warm Dimming 1,900K to 3,000K (WD)
  Tunable Color 2,000K to 5,500K (TC)
- CRI: 90Ra
- Wireless: ZigBee (Atmel SAM R21)
- Dimension (L*D): 50mm x 73.5mm

FUNCTIONAL BLOCK DIAGRAM

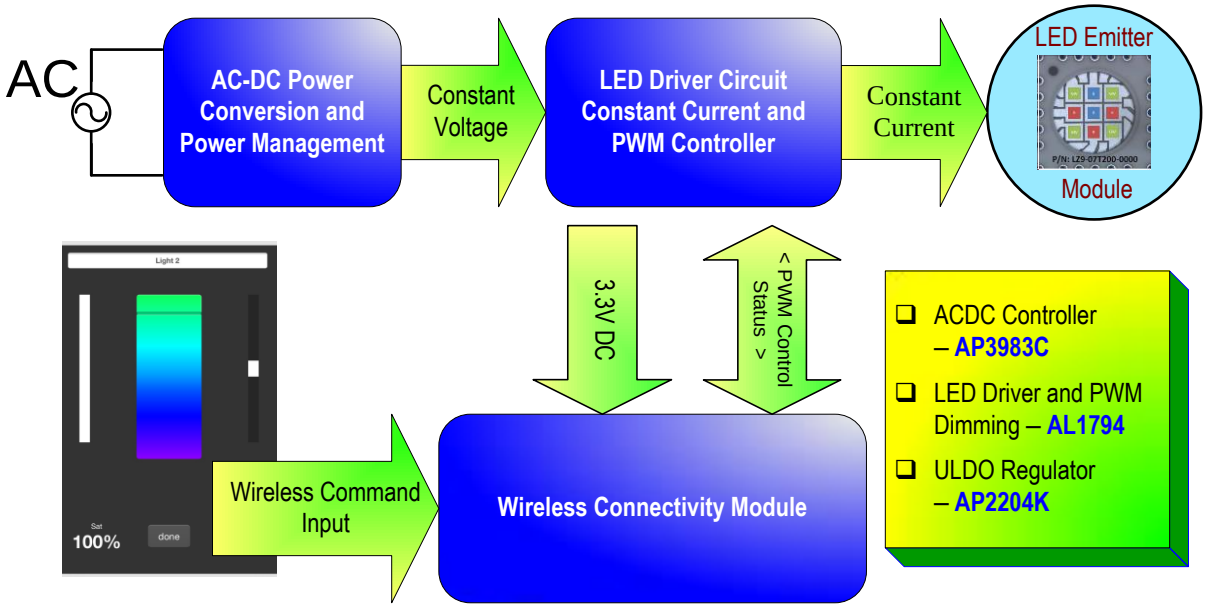


Figure 1 - Functional Block Diagram for Smart Connected Light Bulb

A typical SCL bulb (Figure 1) consists of four major functional blocks:

1) AC-DC Power Conversion - It converts AC input to one or multiple desired output DC Constant Voltages (CV). For a SCL bulb, two or more CVs might be required to better support various DC power requirements from Emitters and Wireless Connectivity MCU.
2) LED Driver - Taking CV inputs to relevant LED driver channels, the LED driver circuitry generates one or more Constant Current (CC) to drive associated LED emitters.
3) Wireless Connectivity Module - The Wireless Connectivity Module consists of an intelligent MCU and RF circuitry to connect a SCL bulb either directly with smartphones or indirectly through WiFi/ZigBee hub, based on a communication protocol (e.g. Bluetooth/BLE, ZigBee, etc.)
4) LED Emitter Module - This is the light source for the SCL bulb. Driven by PWM dimming signal(s) from Wireless Connectivity MCU, emitters on the LED Emitter Module are properly mixed to generate desired light output - either brightness adjustment, Corellated Color Temperature (CCT) tuning, or color mixing.

APPLICATION DESCRIPTION

➢ Power Board (PB) Application Description

The PB design (Figure 2) is based on AP3983C PSR AC/DC Switcher IC (with integrated MOSFET referred in the Key Component Section) to be capable of power rating up to 7.5W (SO-7 Package). To support both emitter strings and attached MCU power, the PB outputs two CVs:

- ✧ Warm Dimming (WD) Lamp
  1) VLED1 - 8.2V for for driving emitter strings of RED, 3-die- in-serial
  2) VLED2 – 7.4V for driving emitter strings of GW (Green-ish White), 2-die-in-seiral and BW (Blue-ish White), 2-die-in-serial, Emitters
- ✧ Tunable Color (TC) Lamp
  1) VLED1 - 11.0V for driving emitter strings of G (Lime-Green White), 3-die-in-serial
  2) VLED2 – 7.4V for driving emitter strings of RED, 2-die- in-serial, and for emitter stings of Blue, 2-die-in-serial.

Note that VLED1 and VLED2 supply constant voltages to attached emitter strings with sufficient voltage headroom (LEDx) for voltage regulation of AL179X (LED Driver IC) to properly function. The maximum VF (Forward Voltage) for Red, Green-ish White and Blue-ish White emitters is 3.5V for 350mA maximum channel current. The maximum VF for RED emitters is 2.6V for 350mA maximum channel current. For 350mA channel current, the maximum LEDx (voltage headroom) is 0.4V. The rqeuired constant voltage to drive wireless MCU (3.3V) is generated from an LDO (AL2204) with input from VLED2 (7.4V).

Figure 2 - AP3983C Power Board (42mm x 30mm, Power Boards)

For the design principles and design examples of AP3983C power board (e.g. Swithcing Frequency, Transformer Design, Feedback Resistors Nework Design), please refer to Diodes' Application Note of AP3983.

➢ Emitter Module Board (EMB) Application Description

Two types of Emitters matching specific needs of WD and TC applications:

- ✧ WD EMB (Figure 3.a) - Suitable for CCT range 3,000K to 1,900K.
  - Emitter Structure - R (3 dies in serial), GW (2 dies in serial) and BW (2 dies in serial) in parallel strings

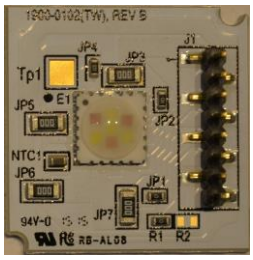


Figure 3.a - 3-Ch WD Emitter Module

- ✧ TC EMB (Figure 3.b) - Suitable for CCT range 6,500K to 2,000K.
  - Emitter Structure - R (2 dies in serial), G (3 dies in serial) and B (2 dies in serial) in parallel strings

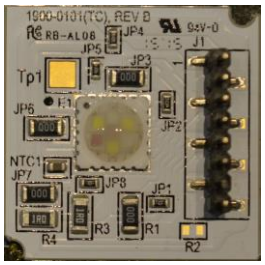


Figure 3.b - 3-Ch TC Emitter Module

For detailed emitter specification, please refer to Appendix II (LED Engin Emitters)

➢ Lens Application Description

PAR16 lamps feature dierctional lighting with narrow beam angle. To create a narrow beam angle as well as to provide much superior color mixing, a Lens is used for achieving both goals (Figure 4).

The key parameters of the lens are as shown below:

- FWHM - Full Width at Half Maximum
- CBCP - Center Beam Candlepower

FWHM	FW10%	Efficiency	CBCP (cd/lm)
27°	57°	94%	2.6

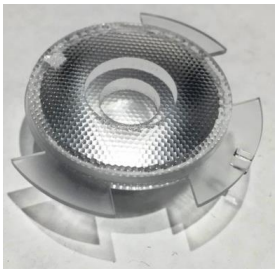


Figure 4 - Lens for PAR16 Lamp

➢ LED Driver and ZigBee Board (LZB) Application Description

A ZigBee IC, Antenna as well as LED driver (AL1794, 4-Channel Linear CCR LED driver) co-exist in the same PCB (Figure 5). In this 3-Ch WD/TC SCL bulb design, the REF (reference current setting resistor) for LED Driver circuit is 8.5KΩ to regulate a total channel current around 350mA for both Channel 1 and Channel 2 and 262.5mA for Channel 3.

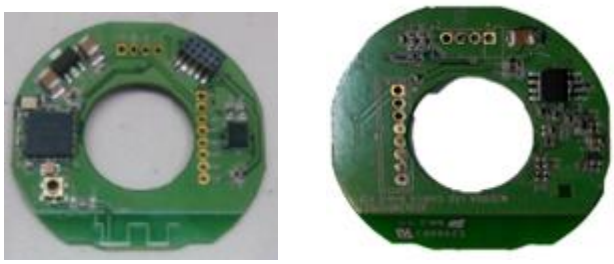


Figure 5 - Wireless & LED Driver Board (41.2mm Outside Ring, 18mm Inside Ring)

PERFORMANCE TESTING

Though with different target CCT Ranges and quality of white light, the PAR16 3-ch WD is comparable to OSRAM's PAR16 2-Channel Tunable White Lightify lamp (http://led.osram.com/led_com/lightify/index.jsp?mkturl=lightify).
The key feature competitive analysis is summarized in Table 1a.

Similarly, the PAR16 3-ch TC is comparable to Philips' HUE Tunable Color lamp (http://www2.meethue.com/en-us/the-range/hue/).
A key feature competitive analysis is summarized in Table 1b.

PAR16 WARM DIMMING LAMP COMPETITIVE ANALYSIS			
NO	Benchmark Item	LIGHTIFY TUNABLE WHITE	LiteON PAR16 (Warm Dimming)
1	Input AC Voltage (V)	220 - 240	90 - 260
2	Power (W)	6	6.5
3	Power Factor	0.56 (230Vac)	0.85 (120Vac) 0.77 (230Vac)
5	Standby Power (W)	0.44W (230Vac)	0.15W (120Vac) 0.4W (230Vac)
6	Start-Up Time (Second)	N/A from Wall Switch 0.4 second from Standby Mode	1.2 second from Wall Switch 0.4 second from Standby Mode
7	Emitter Module	Individual Emitters (2,700K W + 6,500K W)	7mm x 7mm 7-die single Emitter
8	CCT Range (°K)	2,700K - 6,500K	1,900K - 3,000K
9	CCT White	Mixing 2,700K+ 6,500K White - Linear Approximation	Warm Dimming - True White by Mixing Wg-Wb-R
10	CRI	81 @ 2,800K	90 @ 3,000K
11	Luminous Flux Φv (lm)	481lm @ 2,800K (RT) 428lm @ 2,800K (hot)	300lm (RT)
12	Beam Angle (°)	32	27
13	Iluminance Ev (Flux - lm/m^2)	966 @ 2,800K	884
14	Efficacy (lm/W)	80 lm/W @ 2,800K	46 lm/W @ 3,000K
15	Wireless Connectivity	ZigBee	ZigBee
16	Dimension (L x D in mm)	58x50	73.5x50

Table 1a - Competitive Analysis Summary of PAR16 3-ch WD SCL Bulbs

PAR16 TUNABLE COLOR LAMP COMPETITIVE ANALYSIS			
NO	Benchmark Item	HUE Tunable Color PAR16	PAR16 (Tunable Color)
1	Input AC Voltage (V)	120	90 - 260
2	Power (W)	6.5	6.5
3	Power Factor	0.55	0.856 (120Vac) 0.772 (230Vac)
5	Standby Power (W)	0.45W	0.31W (120Vac) 0.47W (230Vac)
6	Start-Up Time (Second)	2.0second from Wall Switch 0.5 second from Standby Mode	1.2 second from Wall Switch 0.4 second from Standby Mode
7	Emitter Module	Individual Emitters (G3-R2-B2)	7mm x 7mm 7-die single Emitter
8	CCT Range (°K)	2,000K - 6,500K	2,000K - 5,500K
9	CCT White	Mixing RGB	Mixing RGB
10	CRI	>80 CRI, 2,000K - 4,000K	90 @ 2,000K 89 @ 2,700K 85 @ 3,000K 77 @ 4,000K 71 @ 5,500K
11	Luminous Flux Φv (lm)	*1 195 lm @ 2,700K (Default Start-Up) *2 145 lm @ 2,000K, *3 210 lm @ 3,000K, *4 300 lm @ 4,000K, *5 230 lm @ 6,500K	(estimate) (6.5W) *1 228 lm @ 2,700K *2 190 lm @ 2,000K, *3 233 lm @ 3,000K, *4 245 lm @ 4,000K, *5 255 lm @ 5,500K (measured) 175lm @ 4000K (4.5W)
12	Beam Angle (°)	38	27
13	Efficacy (lm/W)	38 lm/W @ 4,000K	38 lm/W @ 4,000K (estimate)
14	Wireless Connectivity	ZigBee	ZigBee
15	Dimension (L x D in mm)	50.8x50.8	73.5x50

Table 1b - Competitive Analysis Summary of PAR16 3-ch TC SCL Bulbs

SYSTEM DESIGN CONSIDERATIONS AND TRADE-OFFS

When design a production-worthy SCL bulb, the system designers have many considerations:

1) Input Voltage Range
2) Power Factor (PF)
3) Efficiency
4) Standby Power
5) Start-Up Time
6) Improving Lumen Output
7) Thermal Management

While 3-ch WD/TC SCL bulbs are designed for full range voltage input, system designs could optimize components for single voltage application (e.g. 120V or 230V). For example, more cost-effective components could be used for 120V-only SCL bulb, including:

1) BD201 (MB06S, see Figure 9 on Page 11)
2) Passive Valley Fill (PVF) Circuit: C201, C202, D201, D202 and D203 (see Figure 9 on Page 11).

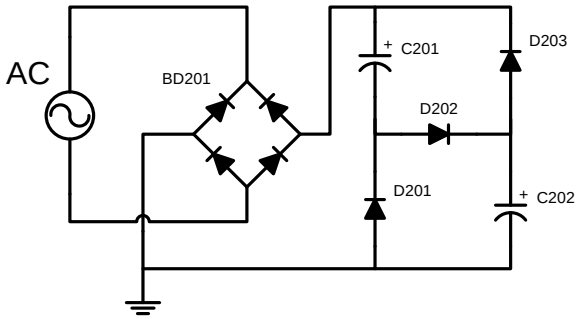


Figure 6 - Bridge and Valley Fill Circuit

AP3983C (SO-8), with integrated MOSFET switch, has its advantages of supporting a cost-effective power board design. The relative small ripple of output voltage for CVs of AP3983C ($V_{peak\text{-}to\text{-}peak}$ ripple < 2.9% of the CV of Emitter Strings) is ideal to support linear Constant Current Regulation (CCR) based LED driver, such as AL1792, with optimal voltage headroom for attached LED emitter strings.

Per Energy Star Compliance requirement, the Power Factor (PF) for over 5W light bulb need to be over 0.7. As the AP3983C does not have built-in Active Power Factor circuitry, a PVF Circuit, consists of C201, C202. D201, D202 and D203 is designed to achieve desired PF over 0.7. A high PF value could be achieved by using larger capacitors (C201 and C202), but at the expenses of longer start-up time, PCB space and cost. The system designers need to select the right balance for the PF value and other considerations.

The system efficiency of 6.5W typical 3-ch PAR16 WD/TC bulbs need to be above 70% based on the proposed two-stage designs. For the Power stage (first stage) efficiency, it is designed to achieve over 75%. While fixed-CCT on-off LED light bulb will have no power consumption when turned off at standby mode, a SCL bulb consumes non-trivial standby power due to constant-on for wireless module connectivity. To save energy consumed during the standby mode, it recommded to stay within 0.5W when in the standby mode for the entire SCL bulb.

Key relevant circuitry which impact efficiency and standby power consuption include:

1) CV Output Voltages (PV1, PV2 - used to generate 3.3V for MCU Power).
2) Pre-loading circuit (R213, R214 and R216, see Figure 9 on Page 11) to prevent spurious output voltage at no load situation for one CV output, but sudden current is drawn by the other CV output.
3) Low VF Drop Super Barrier Rectifier (D211 and D212, see Figure 9 on Page 11)
4) Start-Up Circuit R201 (see Figure 9 on Page 11).

An alternative quick dynsmic startup circuit can be used to replace the resistor start-up circuit to shorten start-up time without static standby power consumptino (Figure 7). During the AC power initial input, Transistor Q1 is turned ON to charge VCC input to AP3983C. Q1 will be shut off after initial start-up time until shut off by returning path from the auxiliary winding when VCC is highter than one threshold voltage below 18V where the Zener diode is clamped at.

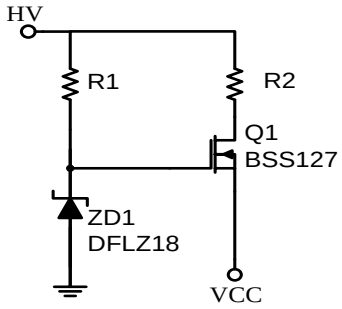


Figure 7 - Dynamic Fast Start-Up Circuit

➢ Improve Lumen Output with Unused Channel 4

AL1794, a 4-channel LED driver, has a fixed channel current ratio of 1:1:0.75:0.25 for Channel 1, 2, 3 and 4 respectively. In the current reference design of PAR16 lamps, only the first 3 LED driver channels of AL1794 are used. The Channel 4 LED driver can be used in parallel to Channel 1, 2 or 3 to enhance lumen output to desired effects. For example, enhancing GREEN channel with Channel 4 driver will enhance the overall lumen output of the TC lamp. Adding Channel 4 to the RED channel will result in stronger warm light output.

➢ Thermal Management Design Suggestion

Thermal management is a critical design consieration as it impacts safety and reliability of the SCL bulbs. Among many good practices used in the power board design for managing thermal issues of SCL bulbs, system designers also need to fine tune the CV output to compensate for V_F fluctuation due to temperature effect. Depending on thermal characteristics of emitters, V_F drops around 5% to 10% range when temperature is increased from 25°C to 125°C. The proposed design is based on a low-cost open-loop CV fine tuning approach by adopting a Negative Temperature Coeffient (NTC) resistor 10K (RT201, Figure 9).

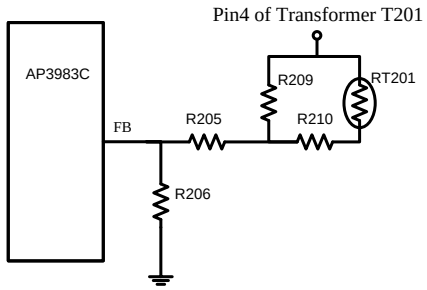


Figure 8 - Thermal Management Circuit

Also, VF matching resistors are used to help matching VF matching between strings attached to a CV source (R3 and R4, see Figure 11.b Page 13). The main purpose is to distribute unused LED power between the resistor and AL1794 less the unused LED power is all absorbed by AL1794 only.

COMPLETE DESIGN SCHEMATICS

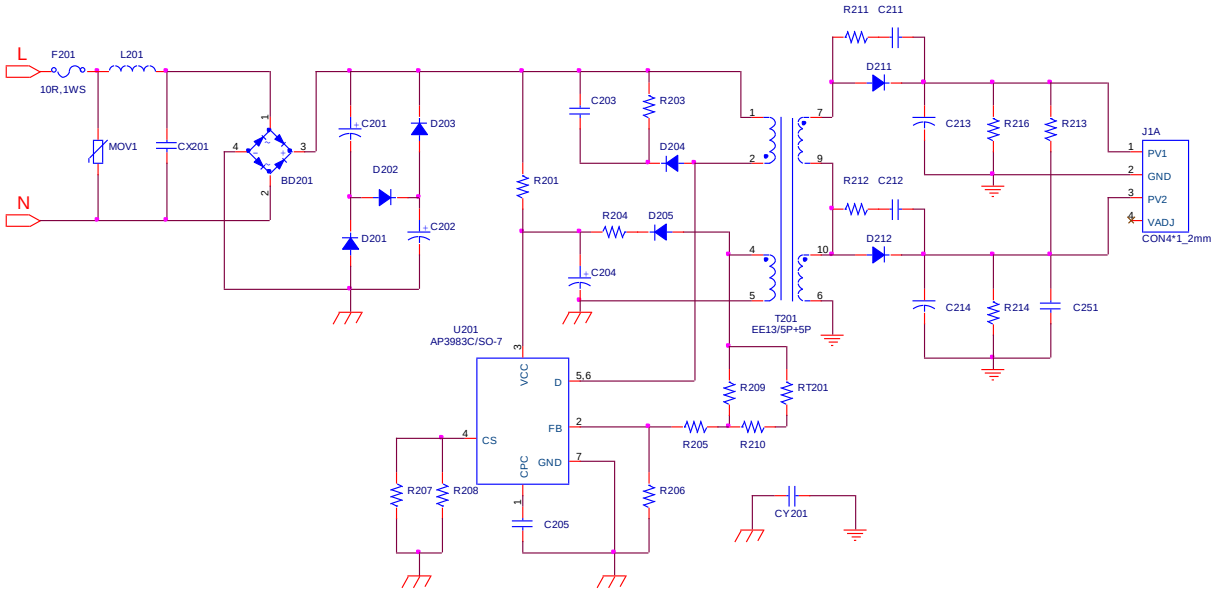


Figure 9 - AP3983C Power Board Schematics

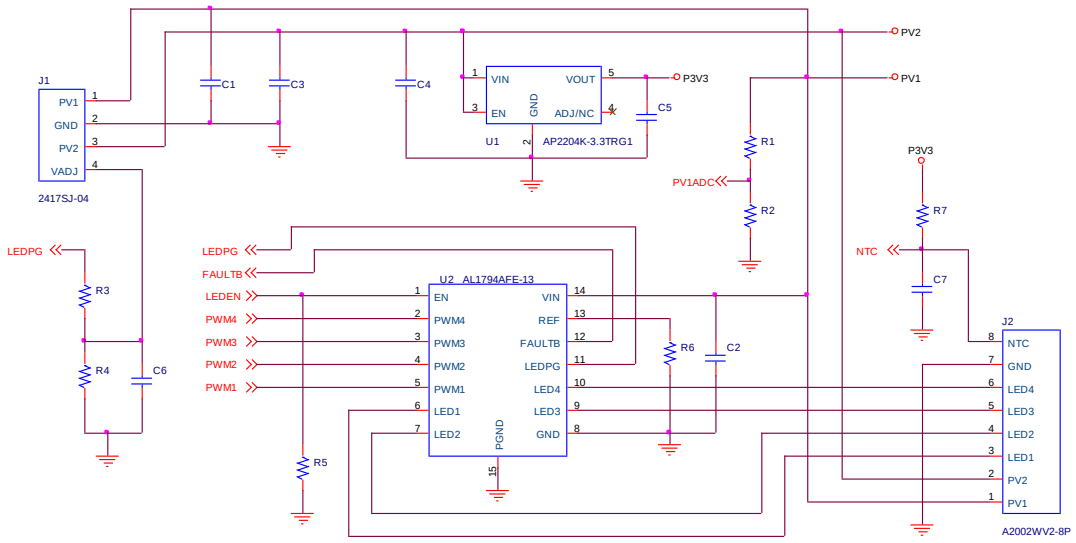


Figure 10.a - LED Driver - AL1794 Schematics

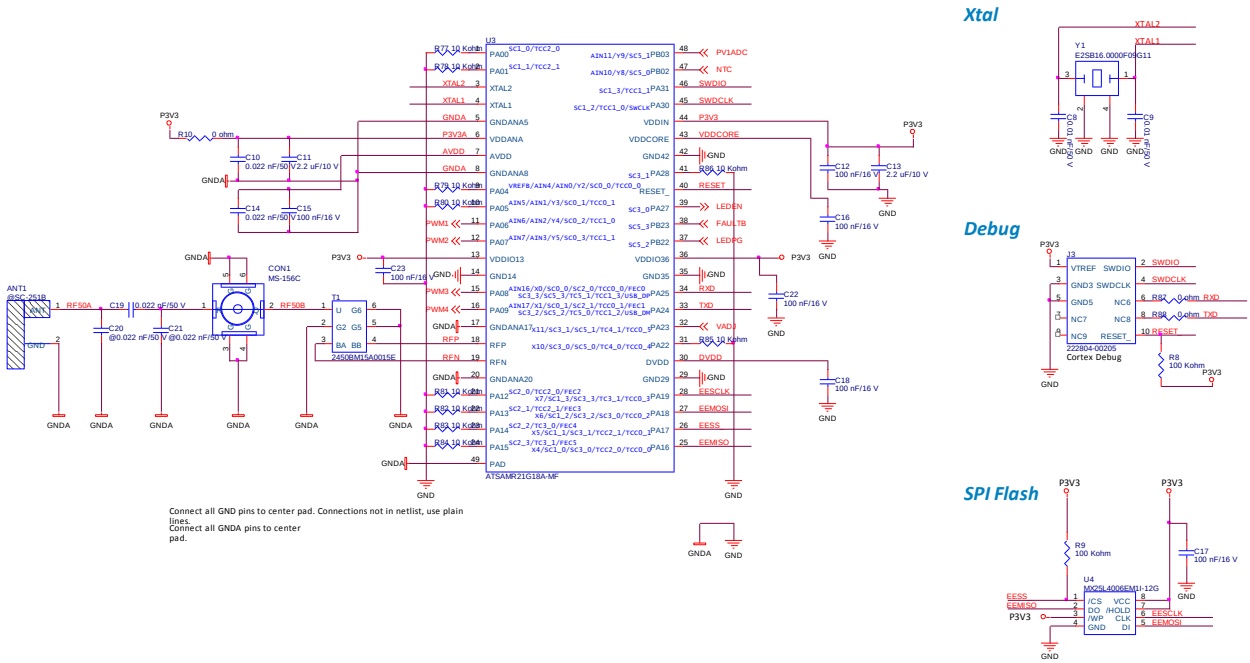


Figure 10.b - LED Driver - Atmel SAM R21 ZigBee Module Schematics

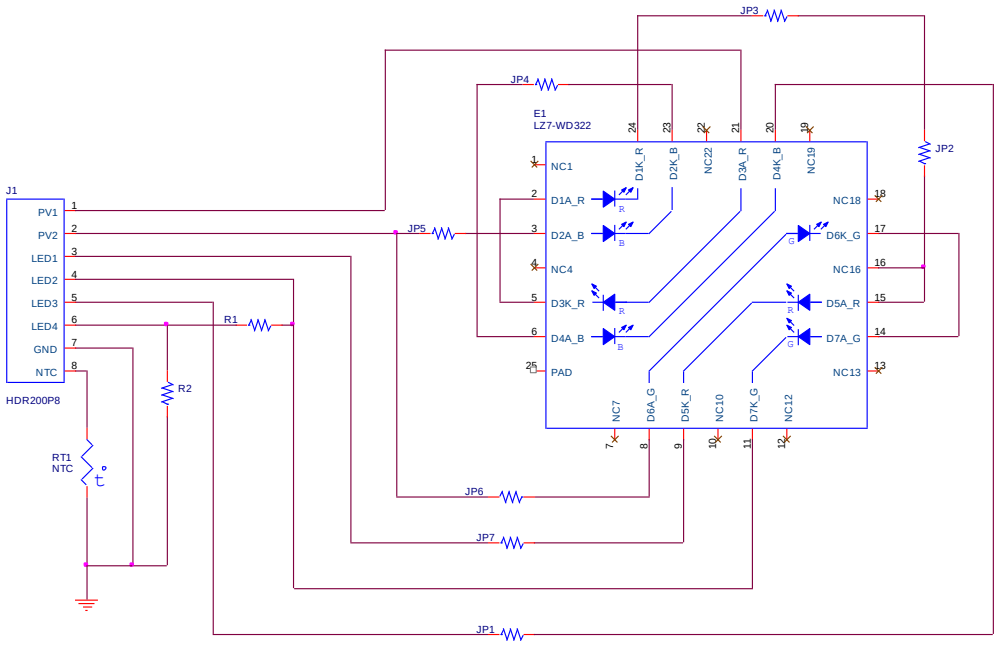


Figure 11.a - 3-Ch Warm Dimming Emitter Module Schematics

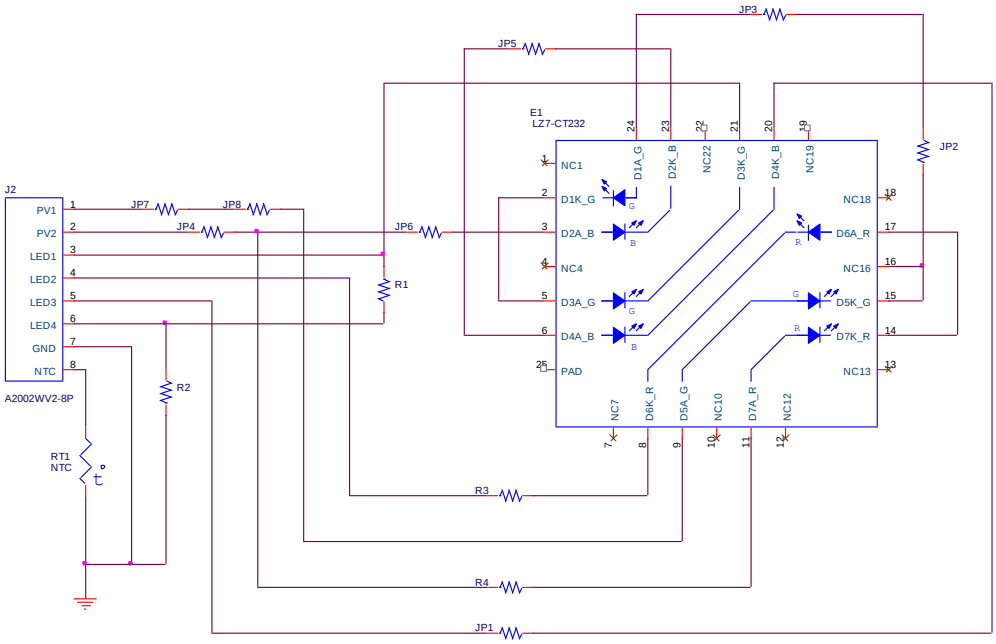
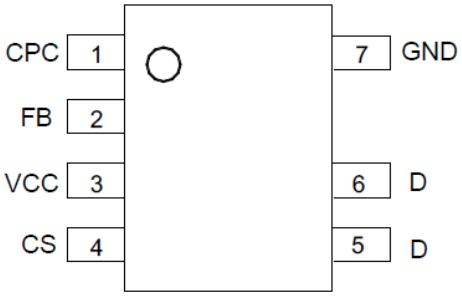


Figure 11.b - 3-Ch Tunable Color Emitter Module Schematics

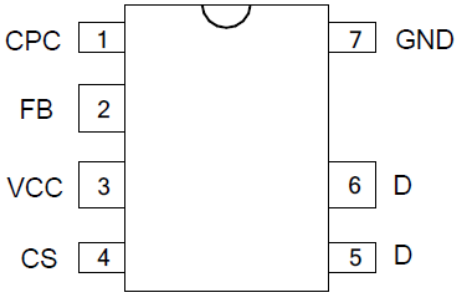
KEY COMPONENTS

➢ **AP3983C - AC/DC Controller**

AP3983C IC PIN OUT ASSIGNMENT



SO-7 (M Package) For AP3983B/C



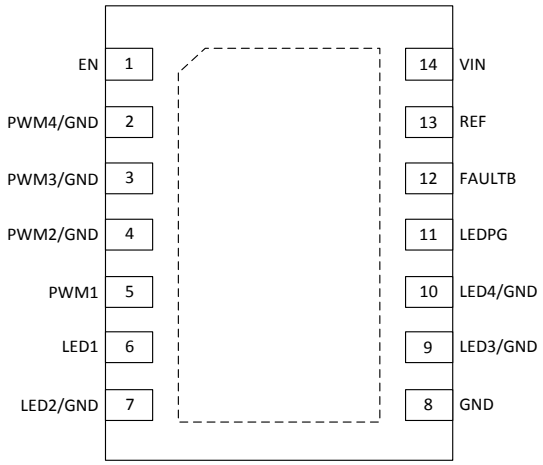
PDIP-7 (P7 Package) For AP3983D

- Primary Side control for Eliminating Opto-coupler and Secondary CV/CC Control Circuitry
- Built-In HV power MOSFET with 650V BV_{DSS}
- Valley-turn on to reduce switching loss
- Up to 80KHz operating frequency at full load for compact size application
- Piece-wise frequency reduction to enhance conversion efficiency and suppress audio noise
- ±5% constant voltage accuracy
- ±7% constant current accuracy
- Open Circuit Protection (OCP), Overall Voltage Protection (OVP), Over Temperature Protection (OTP)
- Short Circuit Protection (SCP) with hiccup
- 3-Segment Drive Current for Radiative EMI Suppression

Pin Name	Symbol	Descriptions
	SO-7 / PDIP-7	
CPC	1	This pin is connected a capacitor to GND to serve as a cable compensation function. Additional resistor in parallel with the capacitor will weaken cable compensation to meet cable-less applications.
FB	2	The voltage feedback is from Auxiliary winding.
VCC	3	This pin receives rectified voltage from the Auxiliary winding of the transformer.
CS	4	It is used for current sense from primary side of the transformer.
D	5, 6	The pin is connected with an internal power MOSFET's drain.
GND	7	The pin is the signal reference ground.

➢ AL1791/2/3/4 - LED Driver Controller

AL1791/2/3/4 IC PIN OUT ASSIGNMENT



- Input Voltage Range: 6.5V to 30V
- 1/2/3/4-channel LED drivers: independent Analog or PWM dimming control for each channel
- Reference Current: Adjustable by an external reference resistor
- Ratio-optimized currents for 4 independent LED channels (AL1794 only): Suitable for Tunable White and Tunable Color
- Low Standby Power: With EN pin
- E-flicker free High Frequency PWM dimming with Deep Dimming Capability: Support 10KHz down to 1.0%, 4KHz down to 0.4%, or 1KHz down to 0.1%
- Internal Protections: Under Voltage Lockout (UVLO), LED string open/short protection
- Over temperature protection (OTP): Thermal shut down and auto thermal recovery
- Fault Reporting: UVLO, OTP, Open, and Short
- LED Power Good Reporting
- Low system BOM cost
- Ambient Temperature Range -40°C to +125°C (Automotive Grade)
- U-DFN4030-14: Available in “Green” Molding Compound (No Br, Sb)
- Totally Lead-Free & Fully RoHS Compliant
- Halogen and Antimony Free. “Green” Device

- **AL1791/2/3/4 Pin Descriptions**

Pin Name	Pin Number	Descriptions
	U-DFN4030-14	
EN	1	Active-high to Enable, Internally Pulled Down
PWM4/GND	2	PWM Signal Input for channel 4, Internally Pulled Down for AL1794. GND for AL1791, AL1792, and AL1793.
PWM3/GND	3	PWM Signal Input for channel 3, Internally Pulled Down for AL1793 and AL1794. GND for AL1791 and AL1792.
PWM2/GND	4	PWM Signal Input for channel 2, Internally Pulled Down for AL1792, AL1793, and AL1794. GND for AL1791.
PWM1	5	PWM Signal Input for channel 1, Internally Pulled Down (Tied to GND when this channel is NOT used).
LED1	6	Channel 1 LED Cathode
LED2/GND	7	Channel 2 LED Cathode for AL1792, AL1793, and AL1794. GND for AL1791.
GND	8	Ground
LED3/GND	9	Channel 3 LED Cathode for AL1793 and AL1794. GND for AL1791 and AL1792.
LED4/GND	10	Channel 4 LED Cathode for AL1794. GND for AL1791, AL1792, and AL1793.
LEDPG	11	LED Power Good Indication. Asserted Low to report insufficient headroom. Needs an external pull-up resistor.
FAULTB	12	Fault Report. Asserted Low to report faulty conditions. Needs an external pull-up resistor.
REF	13	Reference Current Setting through External Resistor (R_{SET})
VIN	14	Voltage Input
Exposed PAD	Exposed PAD	Exposed pad. Internally connected to GND. It should be externally connected to GND and thermal mass for enhanced thermal impedance. It should not be used as electrical conduction path.

BILL-OF-MATERIAL – ACDC Poweer Board

Item	QTY	Reference	Part	Package	Description	Supplier
1	1	BD201	SMD	RH06	Bridge,600V/0.5A,MB6S	Diodes, Inc.
2	1	CX201	DIP	RP	RP 0.1uF/450V	
3	1	CY201	DIP	Y-CAP	Y1 102M/500V	
4	2	C202, C201	DIP	8X10mm	E.C,CD11GD,105°C,6000H,10uF/200V, 8X9mm	
5	1	C203	SMD	C1206	1nF/1000V,NPO	
6	1	C204	SMD	C1206	10uF/25V,X7R	
7	1	C205	SMD	C0603	100nF/25V,X7R	
8	1	C211, C212	SMD	C0805	470pf /100V,X7R	
9	1	C251	SMD	C0805	NC	
10	2	C213, C214	DIP	8X12mm	E.C,RS,105°C,7000H,470uF/16V, 8X12mm	
11	5	D201, D202, D203, D204, D205	SMD	SOD-123F	S1MWF 1A-1000V	Diodes, Inc.
12	2	D211, D212	SMD	SOD-123	SBR2A40P1,40V/2A	Diodes, Inc.
13	1	U201	SMD	SO7	AP3983C IC	Diodes, Inc.
14	1	MOV1	DIP	Varistor	07D471K	
15	1	RT201	SMD	R0603	NTC Resistor 10K,TSM1A103F34D1RZ	
16	1	R201	SMD	R1206	600K/500V, 1%,1/8W	
17	1	R203	SMD	R1206	150K, 5%, 1/4W	
18	1	R204	SMD	R0603	10R, 5%, 1/10W	
19	1	R205	SMD	R0603	45.3K, 1%,1/10W (49.2K for TC)	
20	1	R206	SMD	R0603	12.7K 1%,1/10W (14K for TC)	
21	1	R209	SMD	R0603	47K, 1%,1/10W	
22	1	R210	SMD	R0603	12.1K, 1%,1/10W (20K for TC)	
23	1	R207	SMD	R0805	2.7R, 1%,1/8W	
24	1	R208	SMD	R0805	1.54R, 1%,1/8W	
25	2	R211, R212	SMD	R0805	22R, 5%,1/8W	
26	1	R213	SMD	R0805	3.9K, 5%,1/8W	
27	1	R214	SMD	R0805	8.2K, 5%,1/8W	
28	1	R216	SMD	R0805	15K, 5%,1/8W (20K for TC)	
29	1	T201	DIP	EE13 5+5Pin	EE13	
30	1	L201	DIP	(Color-coded inductor)	3.3mH,120mA	
31	1	F201	DIP	Fuse	10R,1WS,5%	
32	-	PCB	FR4 PCB		30.5*42*1mm 2Layers 1oz by Lead free tin	
TOTAL	39				Power Board Electronic Parts	

BILL-OF-MATERIAL – LED Drive Board (LED Driver and ZigBee)

LED Driver System BOM					
#	**Name**	**QTY**	**Part Number**	**Manufacturer**	**Description**
1	U1	1	AP2204K-3.3TRG1	Diodes, Inc.	Wide input voltage range, 150mA ULDO regulator, SOT23-5
2	U2	1	AL1794AFE-13	Diodes, Inc.	Quad Channel Current-Ratio-Optimized LED Driver with Analog and PWM Dimming U-DFN-4030-14
3	R1	1	100K		Voltage Divider Resistor, Full Voltage input 11.0V
4	R2	1	10K		Voltage Divider Resistor, feedback 1.0V to PV1ADC
5	R3	1	10K		Voltage Divider Resistor, for Adjusting CV Output from Power Stage
6	R4	1	10K		Voltage Divider Resistor, for Adjusting CV Output from Power Stage
7	R5	1	100K		Pull-down Resistor to EN Pin from GPIO of MCU
8	R6	1	6.04K		Reference Channel Current Resistor, to generate 500mA (Maximum Channel current)
9	R7	1	23.2K		Pull-up resistor for NTC (3.3V)
10	C1, C3, C5	3	10uF/25V		
11	C2, C4, C6, C7	4	100nF/16V		
12	J1	1	Connector		
TOTAL		**17**			LD Board-Driver Electronic Parts

ZigBee Module System BOM (Key Parts only)					
#	**Name**	**QTY**	**Part Number**	**Manufacturer**	**Description**
1	U3	**1**	ATSAMR2118A-MF	Atmel	ZigBee 2.4GHz IC
2	T1	1	2450BM15A0015E		
3	U4	1	MX25L4006EM1I-12G		SPI Flash
4	Y1	1	E2SB16.0000F09G11		Crystal OSC
5			ANT1 @SC-251B		Embedded Antenna
TOTAL		**-**	-		LD Board-ZigBee Electronic Parts

BILL-OF-MATERIAL – Emitter Board

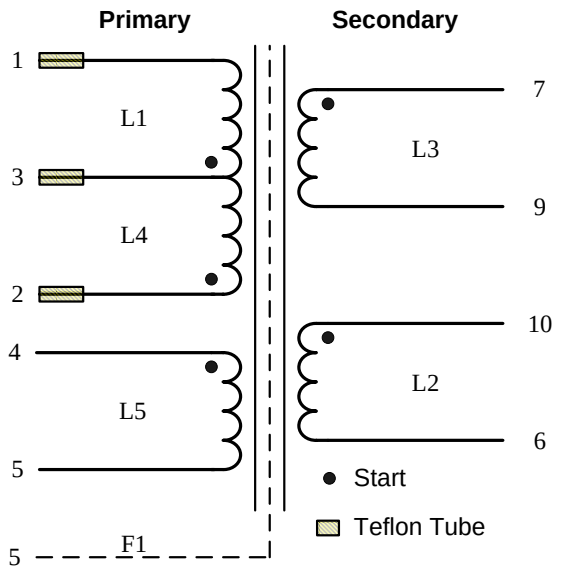
Tunable Color Emitter Module System BOM					
#	**Name**	**QTY**	**Part Number**	**Manufacturer**	**Description**
1	E1	1	LZ7-CT232	LED Engin	LZ7-07T200-0000 (Tunable Color)
2	R1	1	0R/1206		Jumper to connected LED4 to LED1, for enhancing LED1 Channel Current by 25%
3	R2	0	-		Not fitted. (For AL1794_LED4 pin grounding)
4	R3, R4	2	1R/1206		VF (Forward Voltage) Matching Resistor
5	JP1,JP2,JP4,JP5,JP8	5	0R/0603		Jumpers
6	JP3,JP6,JP7	3	0R/1206		Jumpers, JP3 and JP6 are also for VF matching resistors
7	J1	1	HDR200P8		Jumper from Emitter Module to Driver PCB
8	NTC1	1	10K/1%/0603/NTC		Thermal management detector component
TOTAL		14			Tunable Color Emitter Board Electronic Parts

Warm Dimming Emitter Module System BOM					
#	**Name**	**QTY**	**Part Number**	**Manufacturer**	**Description**
1	E1	1	LZ7-CT322	LED Engin	LZ7-07T100-0000 (Warm Dimming)
2	R1	1	0R1206		Jumper to connected LED4 to LED2, for enhancing LED2 Channel Current by 25%
3	R2	0	-		Not fitted. (For AL1794_LED4 pin grounding)
4	JP5,JP6,JP7	3	0R/1206		Jumpers and VF (Forward Voltage) matching resistors
5	JP1,JP2,JP4	3	0R/0603		Jumpers
6	JP3	1	0R/1206		Jumper
7	J1	1	HDR200P8		Jumper from Emitter Module to Driver PCB
8	NTC1	1	10K/1%/0603/NTC		Thermal management detector component
TOTAL		11			Warm Dimming Emitter Board Electronic Parts

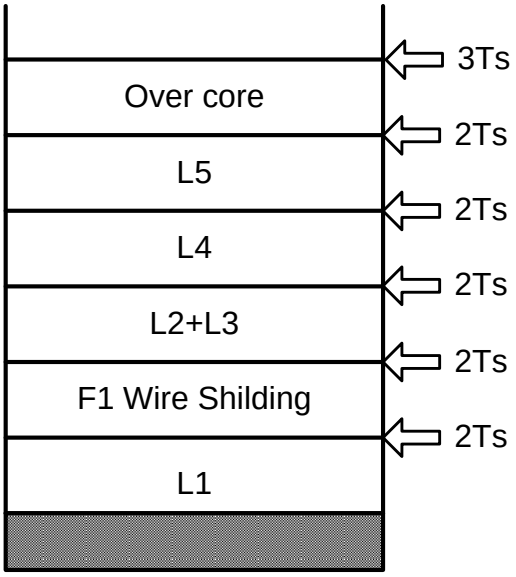
APPENDIX I - EE13 TRANSFORMER SPEC

A. Transformer Pin & Wire Description (PAR16 WD)

Circuit：



Cross sectional view：



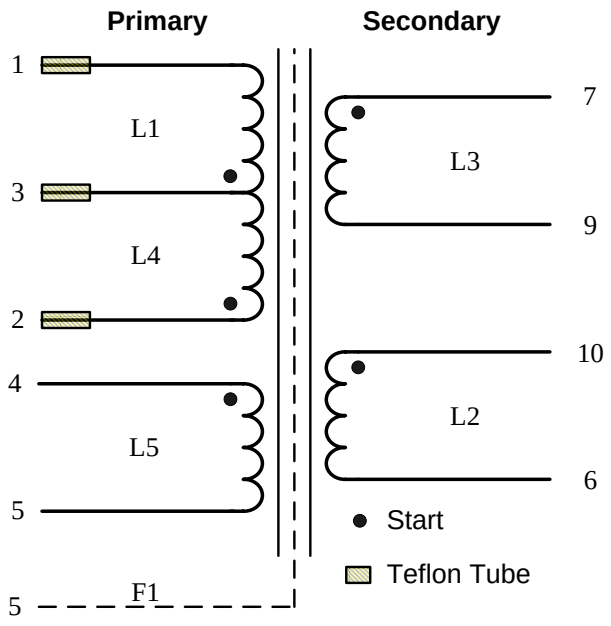
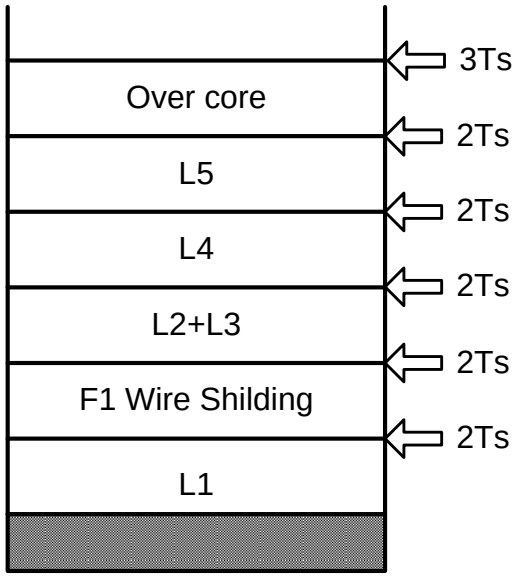
	Pin definition (Start→End)	Wire (φ)	Turn (Ts)	Layers	Layers of Tape
L1	Pin3 to Pin1	2UEW-B 30#AWG x 1P	67	3	2Ts
F1	Pin5 -- Floating	2UEW-B 36#AWG x 1P	full layer	1	2Ts
L2	Pin10 to Pin6	Triple wire-B 28#AWG x 1P	7	0.8	
L3	Pin7 to Pin9	Triple wire-B 28#AWG x 1P	1	0.2	2Ts
L4	Pin2 to Pin3	2UEW-B 30#AWG x 1P	51	2	2Ts
L5	Pin4 to Pin5	2UEW-B 34#AWG x 1P	18	1	2Ts
	OVER CORE				3Ts

Note.
1. EE13 Bobbin 5+5Pin
2. Output for Warm Dimming (7.4V + 6.7V turn Ratio)

B. Electrical Characteristic :

#	Test Item	Winding	Pin	Rating	Tolerance	Remark
2.1	Inductance	L1+L4	#1 to #2	0.8mH	+/-5%	1KHz / 0.4V
2.2	Leakage Inductance	L1+L4	#1 to #2	100uH	Max	10KHz / 0.4V

C. Transformer Pin & Wire Description (PAR16 CT)

Circuit：	Cross sectional view：
	

	Pin definition (Start→End)	Wire (φ)	Turn (Ts)	Layers	Layers of Tape
L1	Pin3 to Pin1	2UEW-B 30#AWG x 1P	67	3	2Ts
F1	Pin5 -- Floating	2UEW-B 36#AWG x 1P	full layer	1	2Ts
L2	Pin10 to Pin6	Triple wire-B 28#AWG x 1P	7	0.7	
L3	Pin7 to Pin9	Triple wire-B 28#AWG x 1P	3	0.3	2Ts
L4	Pin2 to Pin3	2UEW-B 30#AWG x 1P	51	2	2Ts
L5	Pin4 to Pin5	2UEW-B 34#AWG x 1P	18	1	2Ts
	OVER CORE				3Ts

Note.
1. EE13 Bobbin 5+5Pin
2. Output for Tunable Color (9.8V + 6.7V turn Ratio)

D. Electrical Characteristic :

#	Test Item	Winding	Pin	Rating	Tolerance	Remark
2.1	Inductance	L1+L4	#1 to #2	0.8mH	+/-5%	1KHz / 0.4V
2.2	Leakage Inductance	L1+L4	#1 to #2	100uH	Max	10KHz / 0.4V

APPENDIX II - LED ENGIN 3-CHANNEL WD and TC EMITTERS

✧ LZ7-07T100-0000 Tunable White (Warm Dimming) LED Emitter

Key Features

- Ultra-bright, ultra-compact tunable white emitter
- Capable of high quality, high CRI white light
- Typical emitter flux output 345lm@ 3000K, 6.4W
- Typical efficacy 54lm/W
- Based on LuxiGen LZ7-series 7-die high power density product platform
- Small high density foot print – 7mm x 7mm
- High luminous flux density with LES 6mm
- Surface mount ceramic package
- Exceptionally low thermal resistance with electrically neutral thermal path
- Lead (Pb) free and RoHS compliant - reflow soldering (up to 6 cycles)

Luminous Flux

Typical		
Luminous Flux (Φ_V) @ I_F = 500mA		
3 Red	2 GreenWhite	2 BlueWhite
210 lm	312 lm	294 lm

Notes:

✓ Luminous flux performance guaranteed with in published operating conditions. LED Engin maintains a tolerance of +/- 10% on flux measurements.

Forward Voltage Bin

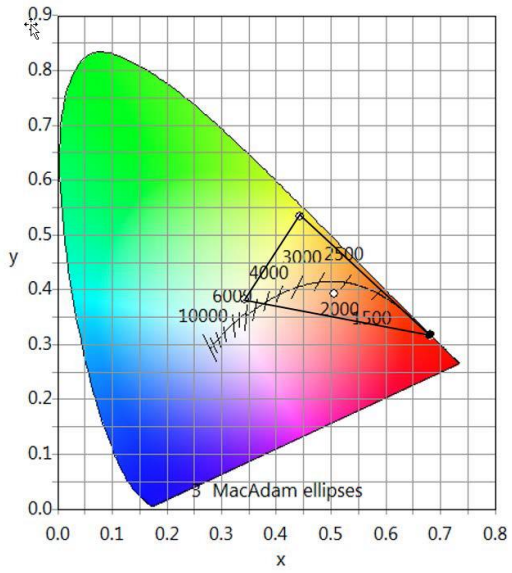
Typical		
Forward Voltage (V_F) @ I_F = 500mA		
3 Red	2 GreenWhite	2 BlueWhite
6.9 V	6.2 V	6.2 V

Notes:

✓ Forward Voltage is binned with all LED dies of a kind connected in series.

✓ LED Engin maintains a tolerance of +/-0.16V for forward voltage measurements for the LEDs.

Tunable Emitter Chromaticity Coordinates



Plotted on excerpt from the CIE 1931 (2°) x-y Chromaticity Diagram.

Chromaticity Bin Coordinates

Typical		
CIE_X @ I_F = 500mA		
Red	GreenWhite	BlueWhite
0.681, 0.318	0.443, 0.533	0.342, 0.383

Notes:

✓ LED Engin maintains a tolerance of +/-0.002 on x, y coordinates.

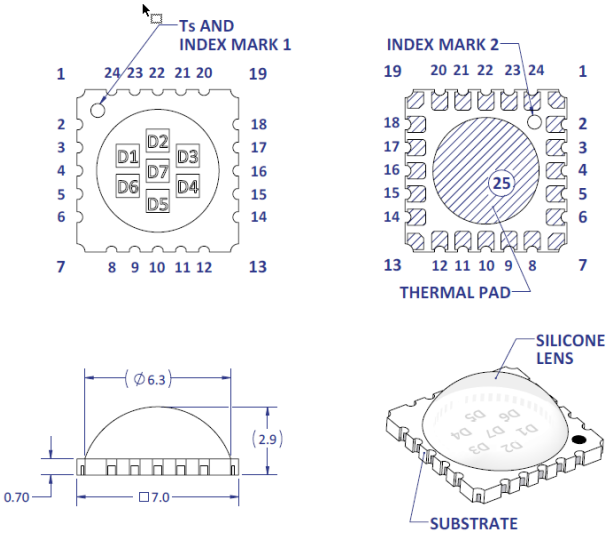
Dominant Wavelength Bins

Typical		
Dominant Wavelength (λD) @ I_F = 500mA		
Red	GreenWhite	BlueWhite
616	571	561

Notes:

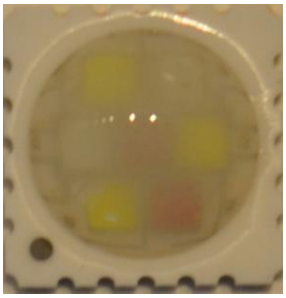
✓ LED Engin maintains a tolerance of +/-1.0nm on dominant wavelength measurements

Mechanical Dimensions (mm)



Emitter Pin Out				
Ch.	**Pin**	**Function**	**Dies**	**String**
1	2	Anode	D1	1x1 (Red)
	24	Cathode		
2	3	Anode	D2	1x1 (B. White)
	23	Cathode		
3	21	Anode	D3	1x1 (Red)
	5	Cathode		
4	6	Anode	D4	1x1 (B. White)
	20	Cathode		
5	15	Anode	D5	1x1 (Red)
	9	Cathode		
6	8	Anode	D6	1x1 (G. White)
	17	Cathode		
7	14	Anode	D7	1x1 (G.White)
	11	Cathode		
Not Internally Connected (Electrically isolated) pins: 1, 4, 7, 10, 12, 13, 16, 18, 19, 22, 25				
Do Not Connect (Electrically Non isolated) pins: none				

✧ LZ7-07T200-0000 Tunable Color (TC) LED Emitter



Key Features

- Ultra-bright, ultra-compact tunable color emitter
- Capable of simulating 16 million shades of color
- Typical emitter flux output 388 lm@3000K, 7.5W
- Typical efficacy 52 lm/w
- Based on LuxiGen LZ7-series 7-die high power density product platform
- Small high density foot print – 7mm x 7mm
- High luminous flux density with LES 6mm
- Surface mount ceramic package
- Exceptionally low thermal resistance with electrically neutral thermal path
- Lead (Pb) free and RoHS compliant – reflow soldering (up to 6 cycles)
- Emitter available on 3-channel MCPCB (optional)

Luminous Flux

Typical		
Luminous Flux (Φ_V) @ I_F = 500mA		
2 Red	3 GreenWhite	2 BlueWhite
144 lm	480lm	63lm

Notes:

✓ Luminous flux performance guaranteed with in published operating conditions. LED Engin maintains a tolerance of +/- 10% on flux measurements.

Forward Voltage Bin

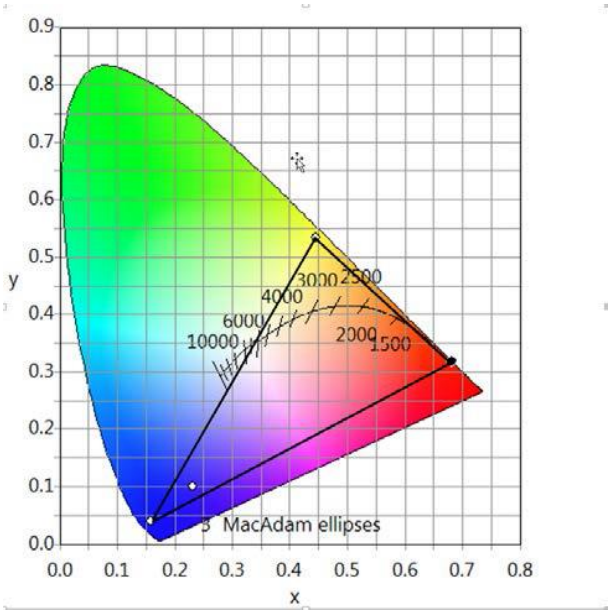
Typical		
Forward Voltage (V_F) @ I_F = 500mA		
2 Red	3 GreenWhite	2 BlueWhite
4.9 V	9.3 V	6.2 V

Notes:

✓ Forward Voltage is binned with all LED dies of a kind connected in series.

✓ LED Engin maintains a tolerance of +/-0.16V for forward voltage measurements for the LEDs.

Tunable Emitter Chromaticity Coordinates



Plotted on excerpt from the CIE 1931 (2°) x-y Chromaticity Diagram

Chromaticity Bin Coordinates

Typical		
CIE_X @ I_F = 500mA		
Red	GreenWhite	BlueWhite
0.691, 0.308	0.445, 0.533	0.158, 0.040

Notes:

✓ LED Engin maintains a tolerance of +/-0.002 on x, y coordinates.

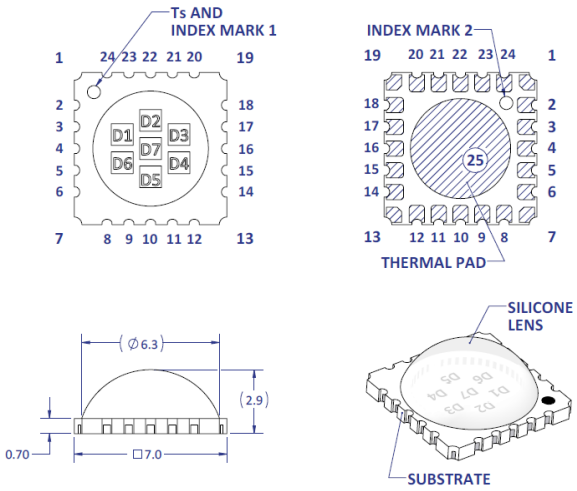
Dominant Wavelength Bins

Typical		
Dominant Wavelength (λD) @ I_F = 500mA		
Red	GreenWhite	BlueWhite
620	571	457

Notes:

✓ LED Engin maintains a tolerance of +/-1.0nm on dominant wavelength measurements

Mechanical Dimensions (mm)



Package Outline Drawing

Emitter Pin Out				
Ch.	Pin	Function	Dies	String
1	24	Anode	D1	1x1 (G. White)
	2	Cathode		
2	3	Anode	D2	1x1 (Blue)
	23	Cathode		
3	5	Anode	D3	1x1 (G. White)
	21	Cathode		
4	6	Anode	D4	1x1 (Blue)
	20	Cathode		
5	9	Anode	D5	1x1 (G. White)
	15	Cathode		
6	17	Anode	D6	1x1 (Red)
	8	Cathode		
7	11	Anode	D7	1x1 (Red)
	14	Cathode		
Not Internally Connected (Electrically isolated) pins: 1, 4, 7, 10, 12, 13, 16, 18, 19, 22, 25				
Do Not Connect (Electrically Non isolated) pins: none				

LED Engin
Web Site: **www.ledengin.com**
Contact: **Cindy Xu (cindyxu@ledengin.com)**

APPENDIX III - ZIGBEE MODULE Atmel SAM R21

✧ Introduction and Specification

- ZigBee IC On board: Atmel SAM R21

http://www.atmel.com/images/45067a-sam-r21_brochure_e_a4_021214_web.pdf

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