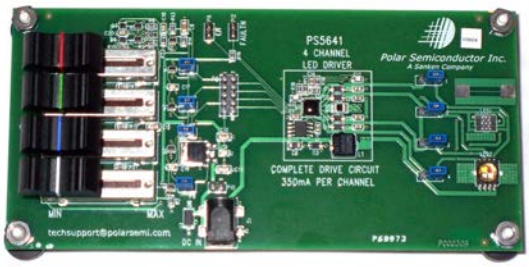
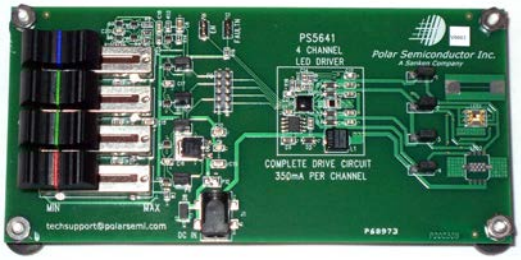
Polar Semiconductor, Inc.
A Sanken Company

PS5641-DB1: Demo Board Users Guide



w/Cree MC-E LED



w/Osram OSTAR SMT LED

PS5641: 4-Channel High Current LED Driver IC

- Schematics and Notes -

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PS5641 Evaluation Board Schematics and Notes

Introduction:

This demonstration board highlights the PS5641 as a unique, compact, and simple to use solution for multi-channel high current LED lighting. The PS5641 is part of a family of LED drivers (including the PS5631 and PS5621) based on an innovative single inductor multiple out (SIMO) architecture optimized for high brightness RGB, RGBW, and tunable white applications.

- PS5641 - 4 Channel Driver (max current per channel 500mA)
- PS5631 - 3 Channel Driver (max current per channel 700mA)
- PS5621 - 2 Channel Driver (max current per channel 1000mA)

The unique control architecture not only allows for uncommonly high currents and voltages (up to 56V), but the operating voltage of each individual LED string is optimized on the fly to minimize the power dissipation in the IC and the final lighting product. Therefore with the proper supply voltage, these drivers provide flexibility to handle strings of 1 to 8 LEDs in series with completely independent PWM dimming for each channel.

The Board:

The board combines a four channel driver, a high brightness multi-color LED, and a simple control mechanism to allow the user to display nearly any color imaginable. The four LED strings are controlled independently via slide pots and a conversion circuit to translate their position into individual PWM dimming control signals. These are connected to the PS5641 through jumpers to provide an elegant self contained demonstration of many of the device's capabilities. By simply sliding the pots you can control the brightness of each individual color. So by adjusting the red, green, and blue LEDs in various combinations you can create very bright light in the color of your choice. Imaginative lighting solutions can be easily created when considering all the options in LED colors: red, green, true greens, blue, deep blues, amber, yellow, cool white, warm white, etc…

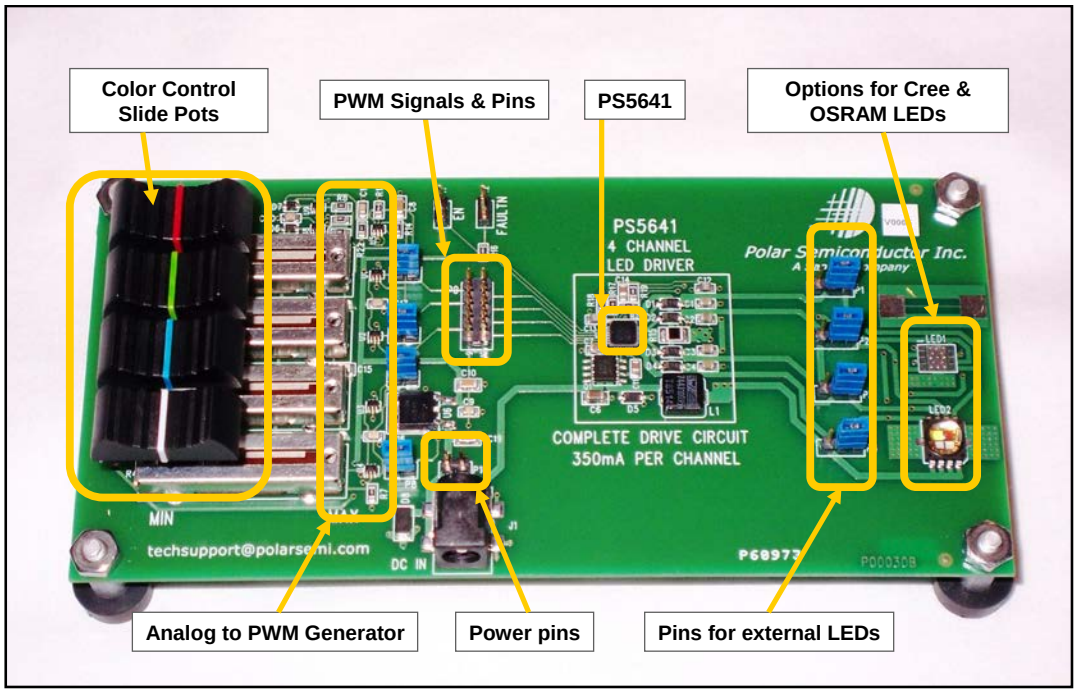

Figure 1: PS5641-DB1 Demo Board

Alternately, the user can remove the jumpers and use the pins (P9 in Figures 5 & 6) as an access port to introduce their own PWM dimming control signals that may be generated from a separate conversion method (e.g., microcontroller based algorithms, DMX interfaces, etc.). Direct connection to the dimming inputs is made by removing the four jumpers from the slide pot section and attaching a ribbon cable to the 2x5 pin header (P9). Also note that forgetting to remove the jumpers will produce unpredictable results, but should not damage the comparators.

The board operates over a Vin range of 16V to 30V DC and is configured to deliver 350mA to each of the LED strings. Power is supplied to the board through two options; traditional header pins (P10 in Figures 5 & 6) or through a 5mm x 2.5mm power connecter (commonly found on Laptop supplies). With the single attached LED, as little as 16V easily drives the circuitry. Thus, two standard 9V radio batteries connected in series can power up the board (Note: If advancing one LED pot dims the others it is time for new batteries).

Shown in Figure 2 below are examples the demo board operating with single and multiple channels driving different colored LEDs. The top row of pictures shows the red, green, and blue LEDs controlled with their individual slide pots. This is easily seen by looking at the position of each color's slide pot. The lower row of photos show colors created with multiple LEDs active: purple is shown with the red and blue channels lit and yellow/gold is seen with the red and green LEDs lit. Finally, the lower right photo of white is with all four LEDs lit (note position of all slide pots). To better show the intensity and color of the light a collimator from Gaggione was used (the colors in the photos appear paler than their true colors due to effects from the camera).

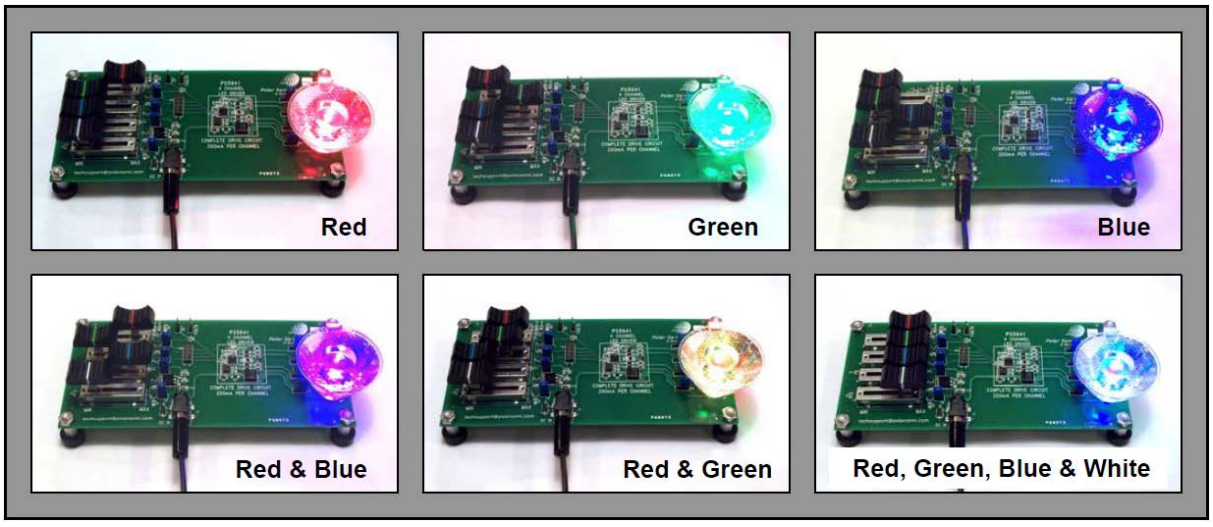

Figure 2: Images of Board Operating with 1, 2 and 4 Channels Operating

Despite the fancy slide pots, the demo board is also a fully functional lab evaluation and solution prototyping board. In addition to introducing their own PWM sources for custom and proprietary color control algorithms, the user can also connect the LED driver outputs to personalized LEDs.

Like the PWM inputs the onboard LED outputs are also connected with jumpers. These can be removed and the common LED+ line is provided on adjacent pins to the LED outputs from the PS5641 for convenient connection to external LED's or test loads. If a jumper is accidently pulled while the LED is lit the resulting fault may require a power down reset as it is latching and disables the output until the power is cycled.

Also note that the demonstration board is available in two versions, each with a different multi-color LED.

- Cree's MC-E LED (4 LEDs: Red-Green-Blue-White)
  - http://www.cree.com

- Osram's OSTAR SMT (4 LEDs: Red-Green-Green-Blue)
  - www.osram-os.com

The boards can easily drive single and multi-color LEDs from other manufacturers as well. Simply pull the jumpers on pins P1-P4 (figures 5 & 6) and connect these pins to the external LEDs. Please remember that the demonstration board is set to deliver 350mA per string so choose your LEDs accordingly.

New smaller "Evaluation Boards" will also be available to prototype innovative lighting solutions over the full range of the PS5641 capabilities. These boards will allow designers to create products with any combination of LEDs, voltages, currents, and control options. The PS5641's ability to drive currents from sub 100mA up to 500mA on all four channels will open the door to many new imaginative product concepts. Note that the Evaluation Boards will be less than half the size of the Demo Boards and do not contain either the slide pots or the LEDs. Device spacing will also be more generous to allow for easy switching of select components to optimize performance for a given application.

Innovative multi-color and variable white lighting systems are now becoming the norm. The ability to provide the market a fully tunable solution that is compact, low cost, and robust is a must for the broad array of LED lighting applications:

- Architectural
- Wall Washing
- LED Light Bar
- Signage
- Industrial & Emergency
- Specialty & Entertainment
- Retail /Commercial
- Patio, Pool, Landscaping…

PS5641 Overview:

The unique PS5641 SIMO (see Figure 3) architecture multiplexes a single inductor (L) and switching transistor (M_{SW}) across four LED strings by sequencing four fully integrated channel switches (LED[1-4]). This topology delivers an amazingly small BOM consisting of the PS5641, one inductor, one MOSFET, and about twenty small discrete components. The total area for the driver circuit is just over 1 square inch.

This fully switch mode scheme enables up to 500mA per channel operation and is independent of forward voltage differences, making the PS5641 a great fit for RGBW and RGBA applications. A patent pending discontinuous conduction mode (DCM) control scheme allows the 4 LED strings to be independently regulated and dimmed with a single current sense resistor (Rcs) and compensation component (Cc). The PS5641, thereby, achieves a reduced PCB footprint and a reduced cost for a similar level of functionality and capability as other four channel solutions (see Figure 3).

The bypass capacitor (C_{O1}-C_{O4}) in parallel with each LED string maintains a DC current, with a small ripple, through the LEDs while the channel diodes allow each parallel combination of capacitor and LEDs to operate at different voltages. The channel diodes can be placed on either the anode or cathode side of the LED strings. As shown in Figure 3 and as done on the demo board the PS5641 can be configured to work with common anode LED arrays by placing the channel diodes on the cathode side.

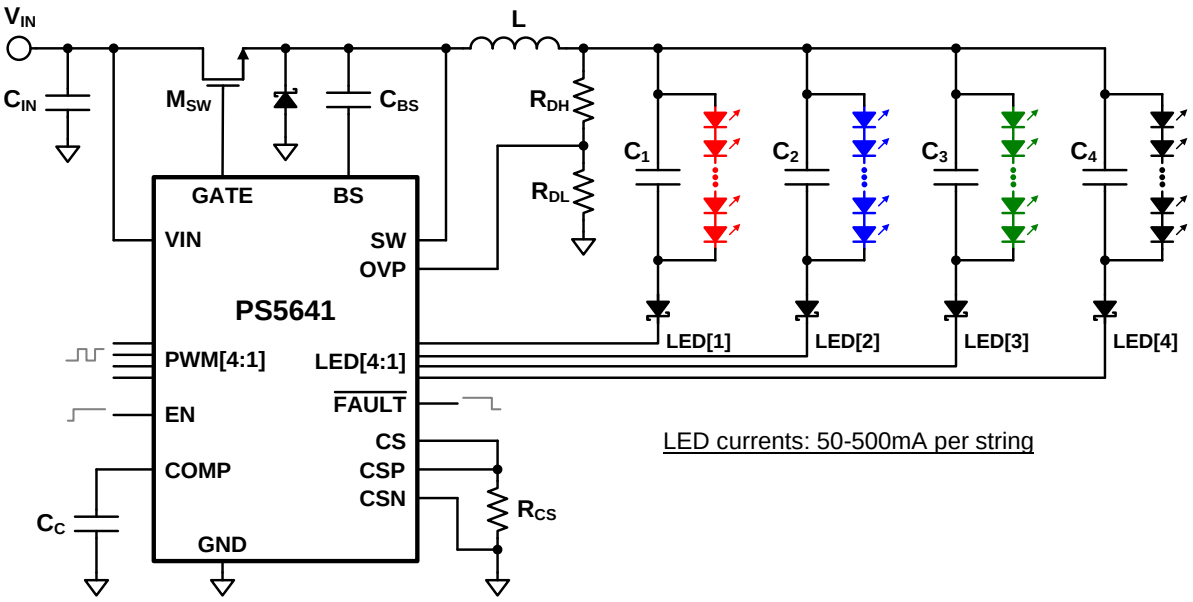

Figure 3: PS5641 Schematic

The PS5641 provides both short circuit and open circuit protection. The OVP pin allows the user to tailor the maximum voltage with a resistor divider (R_{DH} and R_{DL}), thereby, allowing the use of lower voltage output capacitors (C_{O1}-C_{O4}). The PS5641 also includes a differential over voltage protection that protects the channel switches (LED[1-4]) from voltages in excess of 24V. When a single channel has an over voltage fault the PS5641 will signal the event by pulling the open drain FAULT pin low and will disable the problem channel until either the EN pin is toggled or the power is cycled.

The PS5641 architecture enables fully independent control of each channel using a patent pending “blank channel” mode dimming scheme. The four output channels each have a dedicated dimming input (PWM1, PWM2, PWM3, and PWM4). The PWM inputs are TTL compatible level digital inputs that simply control whether the corresponding channel is on or off, respectively, with a logic high or low input.

Each PWM channel on the PS5641 is equipped with a dedicated synchronization module that allows the PWM input sequence to be generated by an external clock that is not synchronized to the PS5641 clock. The PWM signal does not directly control the output channel, but the duty cycle that is applied at the PWM input is maintain at the output. It is best to generate PWM signals that are out of phase with one another to reduce high current surges, but the PS5641 is designed to operate with in phase PWM signals as well.

To facilitate small and compact system designs the PS5641 is packaged in an industry standard 28 pin, 5mm x 5mm QFN. The device also has an exposed pad for robust thermal performance.

PWM Generator Section:

The PWM generator (Figure 4) is built with small components so it will not distract from emphasizing the small footprint of our LED controller. The three comparators on the left comprise a triangle wave oscillator which should be familiar to fans of the legendary 555 timer. A comparator with hysteresis replaces the customary RS flip flop. The oscillator is inherently referenced to the potentiometers, so we can approximate a log function with only four additional resistors from wiper to ccw on the pots. The 10K feedback resistor and 1 μF capacitor to ground at the ADCMP601's inverting input set the frequency range. The lowest PWM frequency will occur at the lowest brightness setting. This also serves to demonstrate how well the PS5641 tolerates PWM frequency shifts provided they remain within data sheet limits.

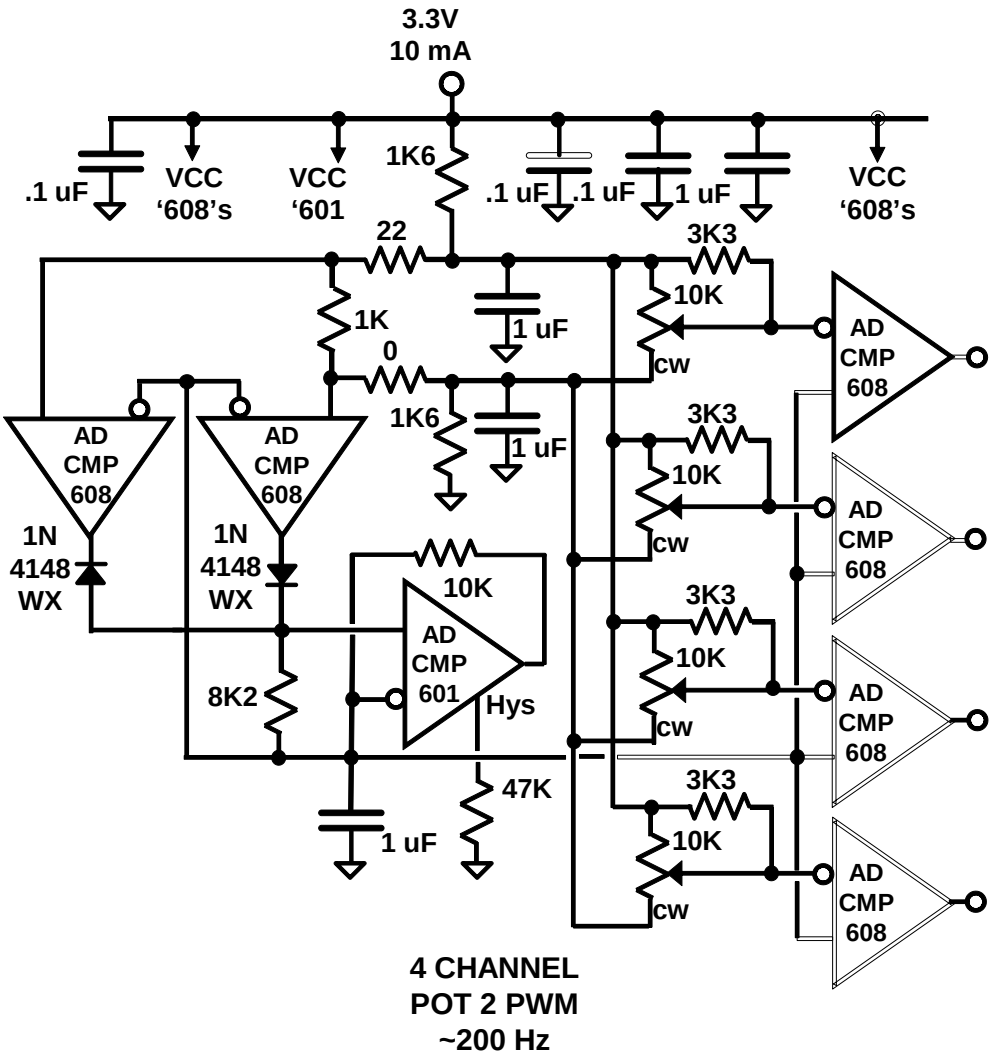

Figure 4: 4-Channel Potentiometer to PWM Converter

This simple PWM generator can also be used with other Eval boards, including our PS5610; the industry's only 2 Amp single channel Buck/Boost/Buck-Boost LED driver.

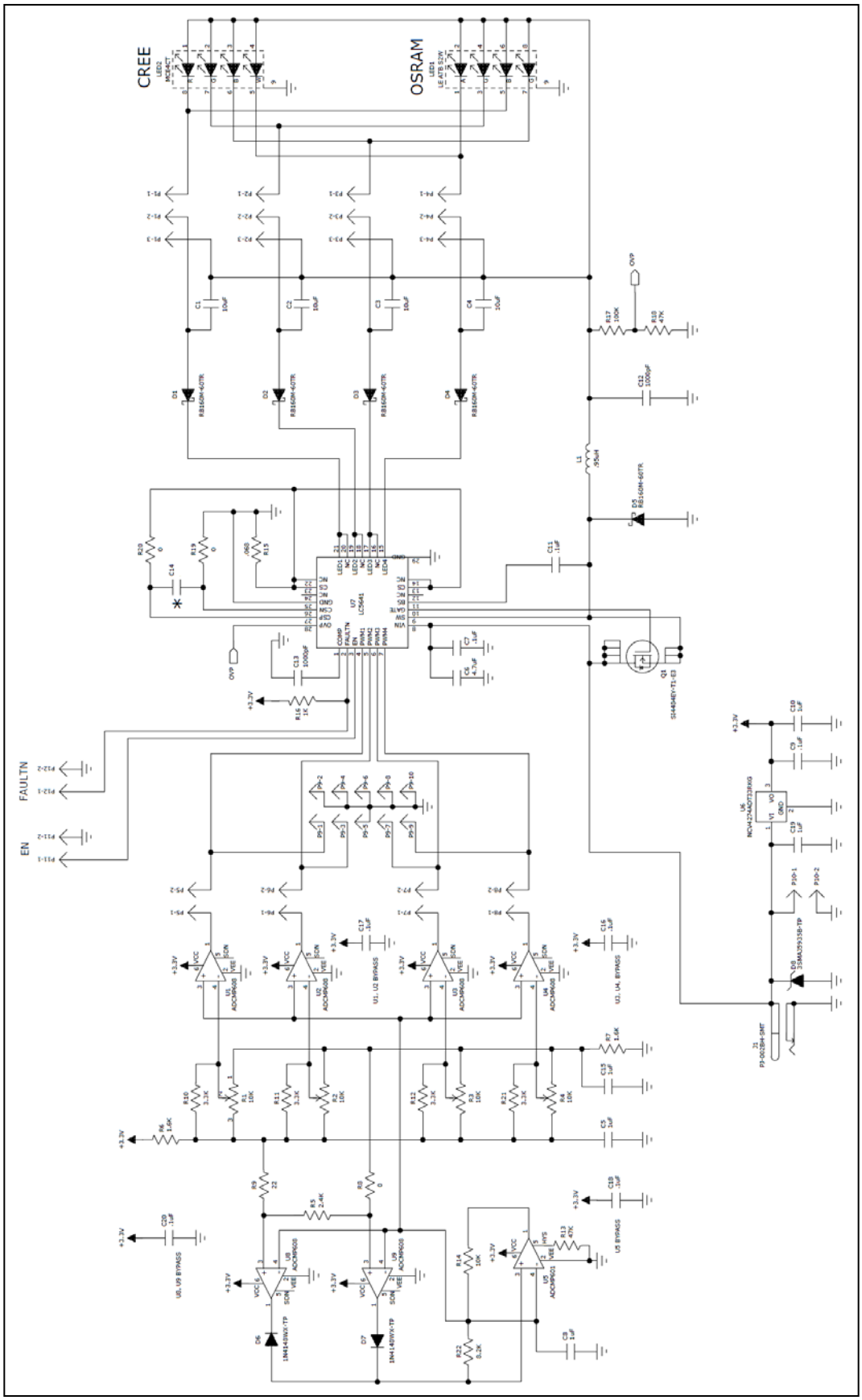

Figure 5: PS5641 Demo Board Functional

Bill of Materials

Qty	Reference	Description	DigiKey#	Package
5	C9, C16-18, C20	Capacitor, .1uF, AVX 08055C104JAT2A	478-3352-1-ND	0805-C
2	C7, C11	Capacitor, .1uF, X7R, TDK C2012X7R2A104K	445-1418-1-ND	0805-C
2	C12-13	Capacitor, 1000pF, Panasonic ECH-U1H102JX5	PCF1328CT-ND	0805-C
-	C14	*Do not populate*	--	--
4	C1-4	Capacitor, 10uF, X5R, AVX 0805YD106KAT2A	478-5165-1-ND	0805-C
5	C5, C8, C10, C15, C19	Capacitor, 1uF, X7R, TDK C3216X7R1E105K/0.85	445-1592-1-ND	1206-C
1	C6	Capacitor, 4.7uF, X5R, Kemet C1206C475K5PACTU	399-5507-1-ND	1206-C
1	P9	Connector, 10PM, 2Row, Header, FCI 68602-110HLF	609-3458-ND	68602-110HLF
7	P5-8, P10-12	Connector, 2PM, Header, FCI 68001-202HLF	609-3469-ND	87220-2
4	P1-4	Connector, 3PM, Header, FCI 68000-103HLF	609-3461-ND	68000-103HLF
1	J1	Connector, Power, Laptop, CUI PJ-002BH-SMT	CP-002BHPJCT-ND	PJ-002BH
2	D6-7	Diode, 1N4148WX-TP, MCC	1N4148WXTPMSCT-ND	SOD323
5	D1-5	Diode, Schottky, Rohm RB160M-60TR	RB160M-60CT-ND	SOD123
1	D8	Diode, Zener, 27V, Micro Com. 3SMAJ5935B-TP	3SMAJ5935B-TPMSCT-ND	SMA
1	U5	IC, Comparator, Analog Dev. ADCMP601BKSZ-REEL7	ADCMP601BKSZ-REEL7CT-ND	SC70
6	U1-4, U8-9	IC, Comparator, Analog Dev. ADCMP608BKSZ-REEL7	ADCMP608BKSZ-REEL7CT-ND	SC70
1	U7	IC, LED Driver, Polar PS5641	NA	VHHD-1
1	U6	IC, Voltage Reg., 3.3V, NCV4274ADT33RKG On	NCV4274ADT33RKGOSCT-ND	DPAK
1	L1	Inductor, .95uH, Wurth 744310095	732-1146-1-ND	744310095
1	LED2	LED, Quad, Cree MCE4CT-A2-0000-00A5AAAA1	MCE4CT-A2-0000-00A5AAAA1CT-ND	MCE4CT
1	LED1	LED, Quad, Osram LE ATB 2SW	475-2805-1-ND	LE_ATB_S2W
1	Q1	MOSFET, Nchan, SI4484EY-T1-E3, Vishay	SI4484EY-T1-E3CT-ND	SO8
3	FID1-3	Mtg Hole .062"	NA	NA
4	ZH1-4	Mtg Hole .156"	NA	NA
1	R15	Resistor, .068, Rohm MCR25JZHFSR068	RHM.068TCT-ND	1210-R
3	R8, R19-20	Resistor, 0, Panasonic ERJ-6GEY0R00V	P0.0ACT-ND	0805-R
1	R9	Resistor, 22 Ω, Panasonic ERJ-6GEYJ220V	P22ACT-ND	0805-R
2	R6-7	Resistor, 1.6K, Panasonic ERJ-6GEYJ162V	P1.6KACT-ND	0805-R
1	R17	Resistor, 100K, Panasonic ERJ-6GEYJ104V	P100KACT-ND	0805-R
1	R14	Resistor, 10K, Panasonic ERJ-6ENF1002V	P10.0KCCT-ND	0805-R
2	R5, R16	Resistor, 1K, Panasonic ERJ-6ENF1001V	P1.00KCCT-ND	0805-R
4	R10-12, R21	Resistor, 3.3K, Panasonic ERJ-6GEYJ332V	P3.3KACT-ND	0805-R
2	R13, R18	Resistor, 47K, Panasonic ERJ-6ENF4702V	P47.0KCCT-ND	0805-R
1	R22	Resistor, 8.2K, Panasonic ERJ-6GEYJ822V	P8.2KACT-ND	0805-R
4	R1-4	Resistor, Pot, 10K, Bournes PTA2043-2015CPB103	NA	PTA2043

The printed circuit board layout is shown below in Figure 6. It is easy to see the simple partitions between the three main functional blocks on the board; color control on the left, driver circuitry in the middle and LEDs on the right.

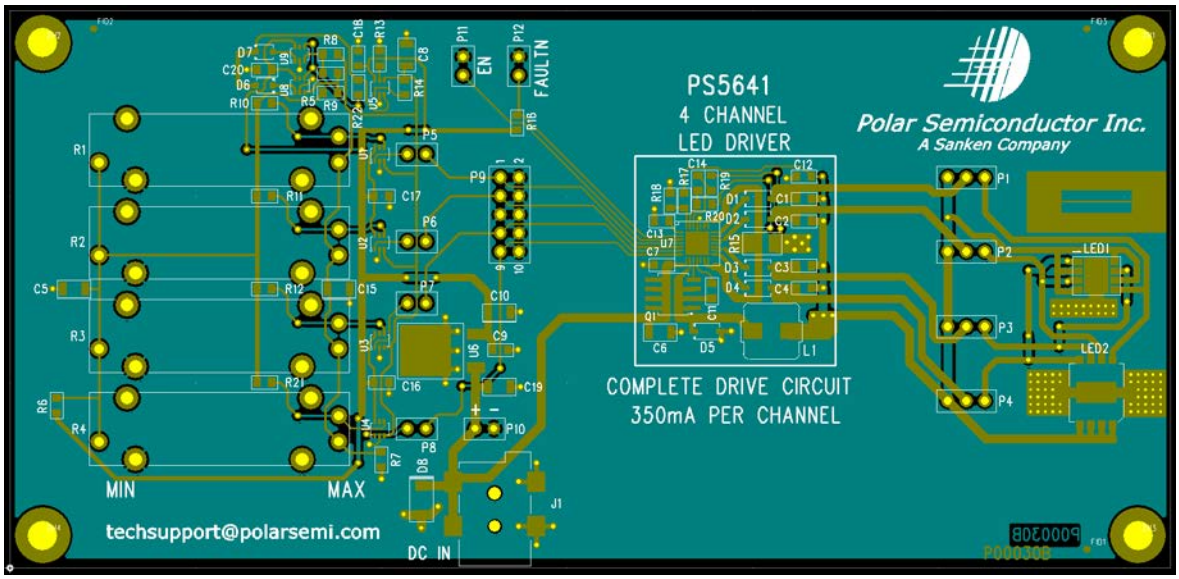

Figure 6: "X-Ray" Artwork View

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