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1–10 V PWM Dimming for CCR Lighting Circuits

Device	Application	Input Voltage	Output Power	Topology
NSI50350AD, NSI50010Y, LM2903	1-10 V LED Dimming	15 Vdc	3.45 W	Comparator for PWM

Schematic

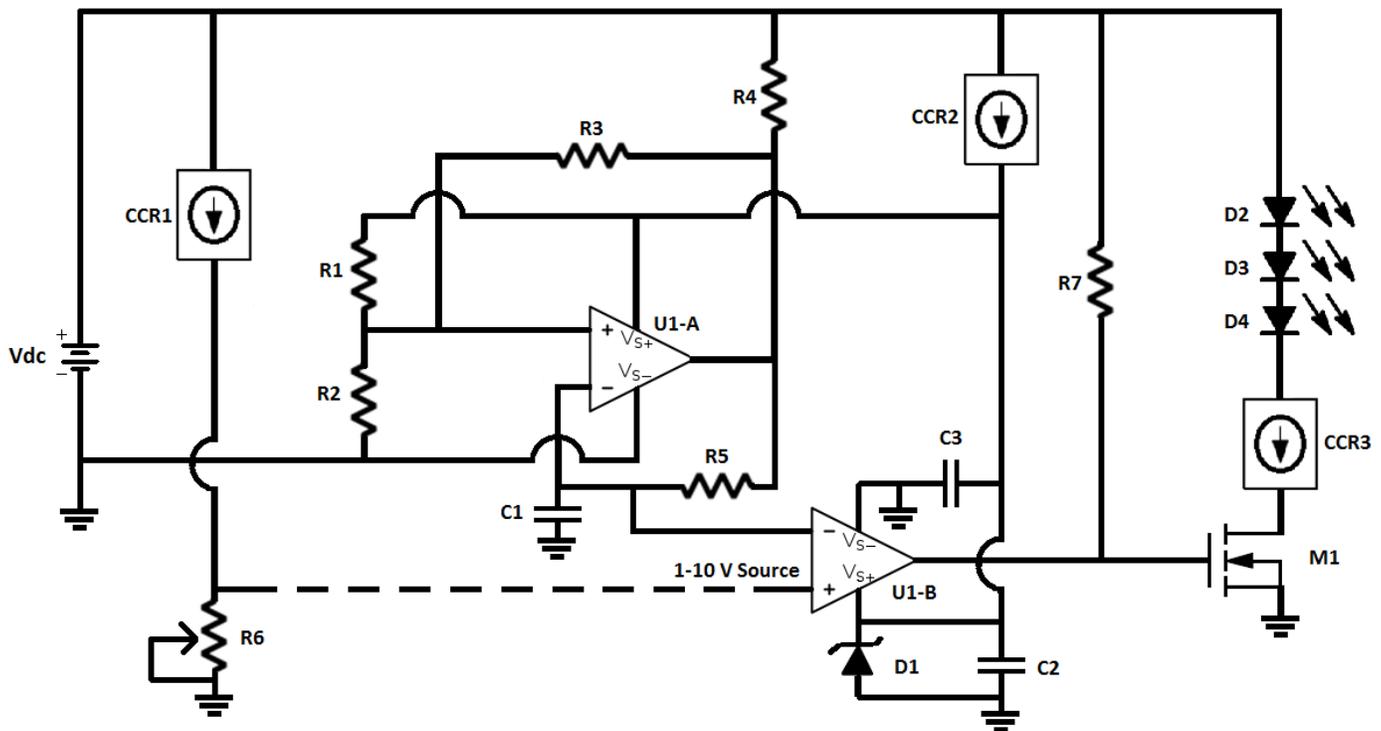


Figure 1: 1-10 V Comparator Dimmable PWM CCR Lighting Circuit.

Circuit Description

This Design Note features a dimmable LED circuit using pulse width modulation (PWM). The dimming circuitry uses two comparators to adjust the brightness of the LEDs. Comparator A (U1-A) generates a Resistor-Capacitor (RC) wave that has a minimum of 1 V_{dc} and a maximum of 10 V_{dc}. Comparator B (U1-B) takes the generated RC wave (V_{compare}) and compares it with the 1-10 V_{dc} input (V_{dim}) of the analog dimmer. When the 1-10

V_{dc} dimming is set to 1 V_{dc} or less, then the LEDs are off. When it is set to 10 V_{dc}, the LEDs will be completely on.

For this circuit, the 1 to 10 V_{dc} dimming is controlled with a 100 Ω to 1 kΩ potentiometer (R6) in series with a 10 mA CCR (CCR1). At 100 Ω and 10 mA, 1 V_{dc} will be available and at 1 kΩ and 10 mA, 10 V_{dc} will be available. If an existing 1 to 10 V_{dc} source is available, then R6 and CCR1 can be removed, and

the source can be substituted. The adjustable source is then connected to the V_{st} of U1-B.

Key Features

- Current regulation to protect LEDs.
- Dimmable circuit for analog dimming of 0/1 to 10 Vdc.
- Single input source with dimming provided by a 0/1 to 10 Volt source.
- No flicker.
- Configurable for greater load voltages.
- Compatible for AC source inputs.

Design Considerations

LED Current and Voltage

With this design, a suitable Constant Current Regulator (CCR) will need to be selected depending on the LEDs chosen. This design is currently set for an input voltage of 15 V and 350 mA through the LEDs. The CCR will provide a constant current over a varying range of input voltage. The CCR V_{ak} needs to be greater than 1.8 V to be in regulation. With a 15 V input and the three 3.3 V LEDs there will be enough overhead V_{ak} for the current to regulate properly. If additional LEDs are needed, simply increase the input voltage allowing for sufficient voltage across the LEDs and the CCR. The Zener diode, D1, will clamp the V_{cc} of the LM2903 (U1-A,U1-B) comparator to 15 V to protect it. The maximum rating for V_{CC} of the comparator is 36 V.

Comparator Voltage Min and Max, Width

Adjusting resistors R1 and R2 will adjust the minimum and the maximum of the RC wave generated from Comparator A shown in Figure 2. This will determine the range offered that controls the PWM function used to switch on and off the MOSFET to control dimming the load. For example, increasing R1 will raise the peak of the RC wave. Increasing R2 will lower the minimum of the RC wave.

Adjusting resistor R4 or the capacitor C1 will change the period of the waveform generated. It is suggested that the frequency be set above 200 Hz to avoid flickering by $\frac{1}{f} = T = 2\pi RC$.

120 - 240 V_{AC} Compatibility

This circuit can also be used with an AC source as well. By taking the original circuit and using a 15 V Zener diode in place of the 15 V_{dc} source, the circuit will function with an AC input. Additional components include a bridge and a smoothing capacitor rectifier to convert the voltage to DC. The load will also need to be increased. In Figure 2, the LED voltage is ~ 120 Volts for use with a 120 V_{AC} (170 V_{peak}) source. Be sure to size the load according to the provided input voltage for the particular design. Since the input voltage is much higher than the original design, a different MOSFET is recommended to accommodate for this change such as the NDD02N60Z 600 V N-Channel Power MOSFET.

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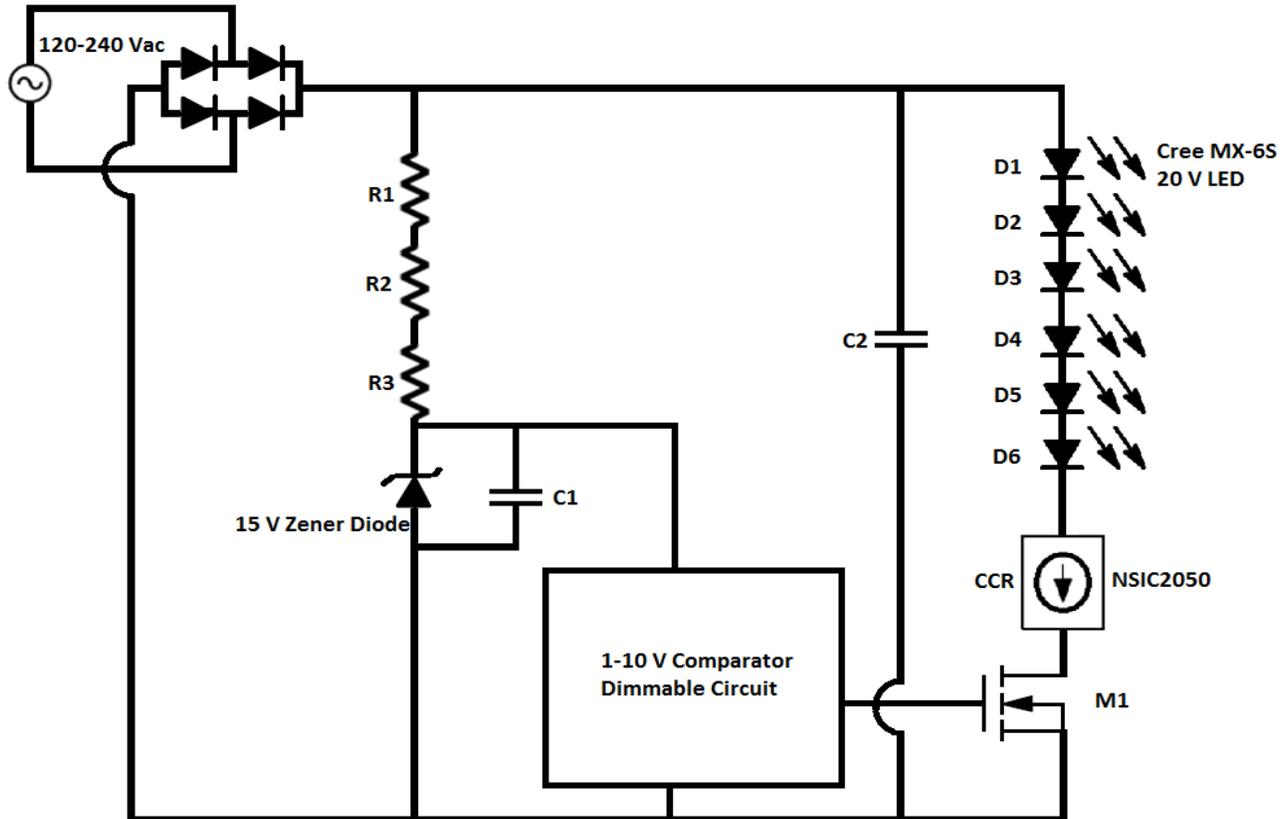


Figure 2: 1-10 V Comparator Dimmable Circuit with AC Source

Bill of Materials

Designator	Manufacturer	Manufacturer Part Number	Quantity	Description	Value	Tolerance
CCR1, CCR2	ON Semiconductor	NSI50010Y	2	Current Regulator	50 V, 10 mA	30%
CCR3	ON Semiconductor	NSI50350AD	1	Current Regulator	50 V, 350 mA	10%
U1-A, U1-B	ON Semiconductor	LM2903	1	Low Offset Voltage Comparator	36 V, 20 mA	N/A
M1	ON Semiconductor	NTD3055-150	1	N-Channel Power MOSFET	60 V, 9 A	N/A
D1	ON Semiconductor	1N5929B	1	Zener Voltage Regulator	15 V, 3 W	N/A
D2-D4	Cree, Inc.	MX6AWT	3	High Power LEDs	3.3 V, 1 A	N/A
R1	Any	-	1	Resistor	2.2 k Ω , 0.25 W	10%
R2	Any	-	1	Resistor	2.2 k Ω , 0.25 W	10%
R3	Any	-	1	Resistor	100 Ω , 0.25 W	10%
R4	Any	-	1	Resistor	3.6 k Ω , 0.25 W	10%
R5, R7	Any	-	1	Resistor	2.2 k Ω , 0.25 W	10%
R6	Any	-	1	Adjustable Resistor	100 Ω to 1 k Ω ,	10%

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					0.25 W		
C1	Any	-	1	Electrolytic Capacitor	0.22 μ F, 20 V	20%	
C2	Any	-	1	Electrolytic Capacitor	4.7 μ F, 20 V	20%	
C3	Any	-	1	Ceramic Capacitor	1 μ F, 20 V	20%	

Waveforms

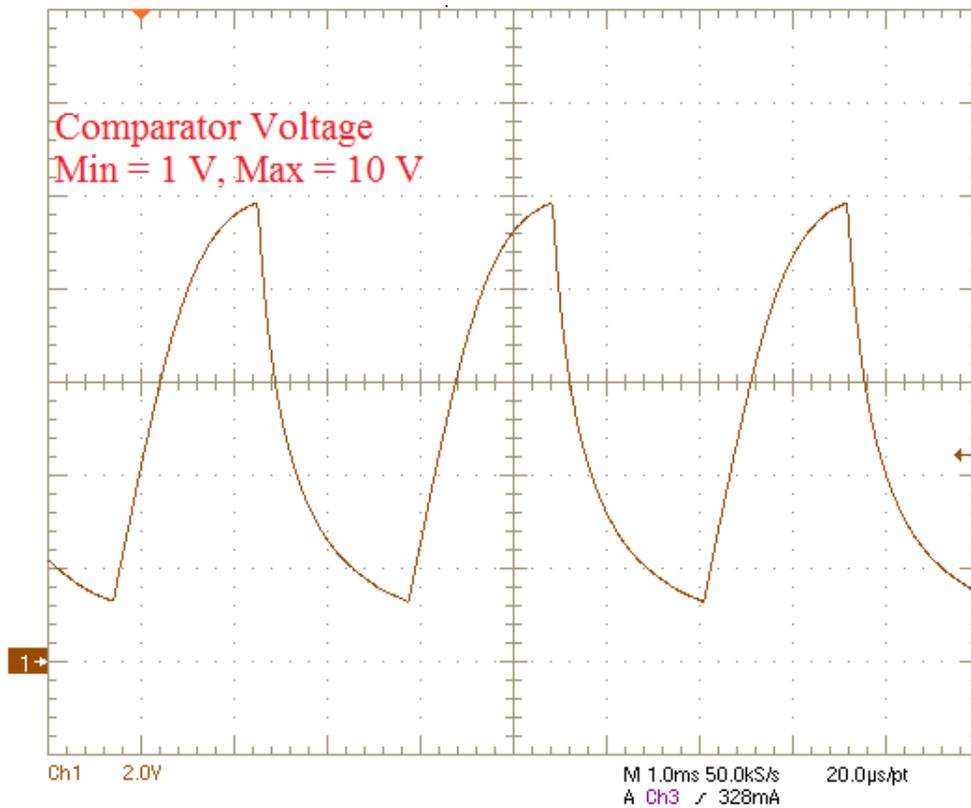


Figure 3: Voltage from Comparator A (U1-A) that will be compared with the 1-10 V_{dc} source.

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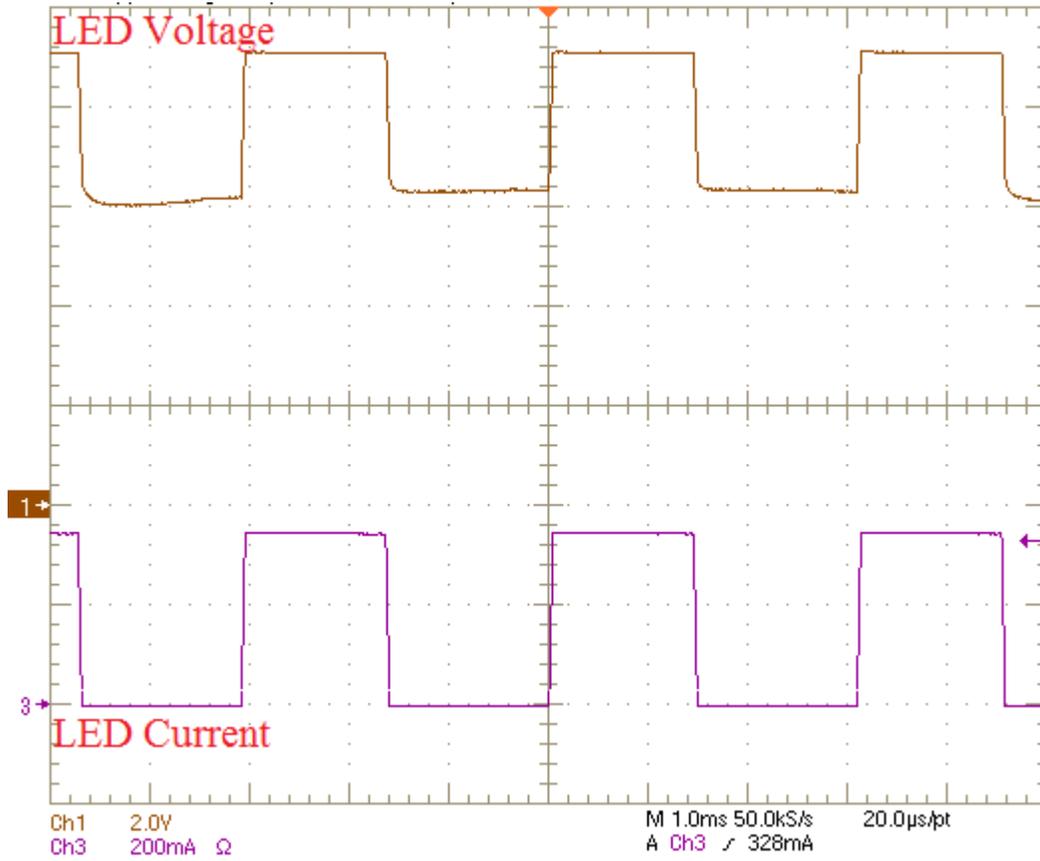


Figure 4: V_{dim} at 33% of $V_{compare}$. The LEDs will be on, but dimmed.

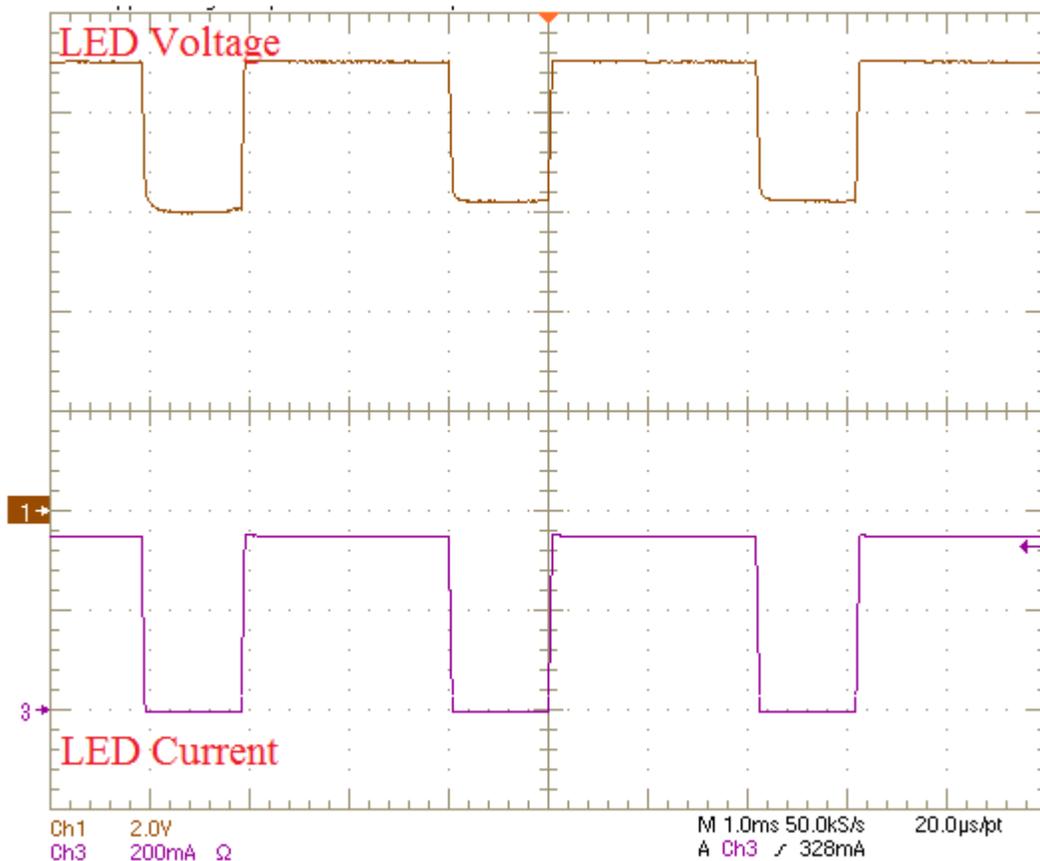


Figure 5: V_{dim} at 66% of $V_{compare}$. The LEDs will be on for a greater amount of time, but not full brightness.

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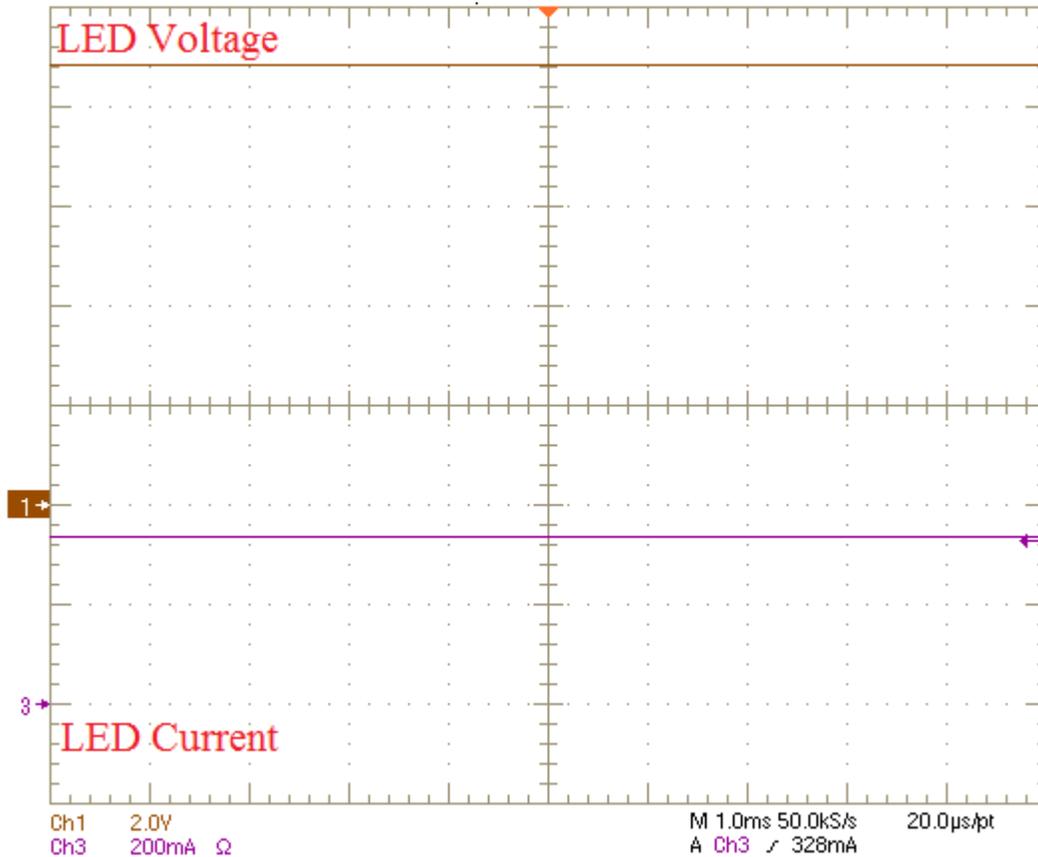


Figure 6: V_{dim} at 100% of $V_{compare}$. The LEDs are completely on during the whole duration.

Appendix A: List of optional 1 to 10 Vdc Sources

Manufacturer	Description	Serial Number
Lutron	Diva 1-10 V Control	DVTV
Philips	High Frequency 1-10V Dimming Ballast	HF-Regulator
Eaton	1-10 V Analogue Dimming Module	F8078

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