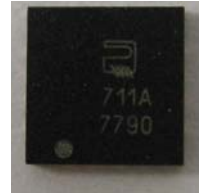


dur-E-volt™ D711A High Voltage LED Driver

Features

- 8V to 450V Input Voltage Range
- Up to 90% Efficiency
- Drives from 1 to Hundreds of LEDs in Series or Parallel Combinations
- Regulated LED Drive Current
- Linear or PWM Luminance Dimming control
- Resistor Programmable Oscillator Frequency
- QFN-16 RoHS Compliant Package
- High Brightness and Regular LEDs



QFN-16

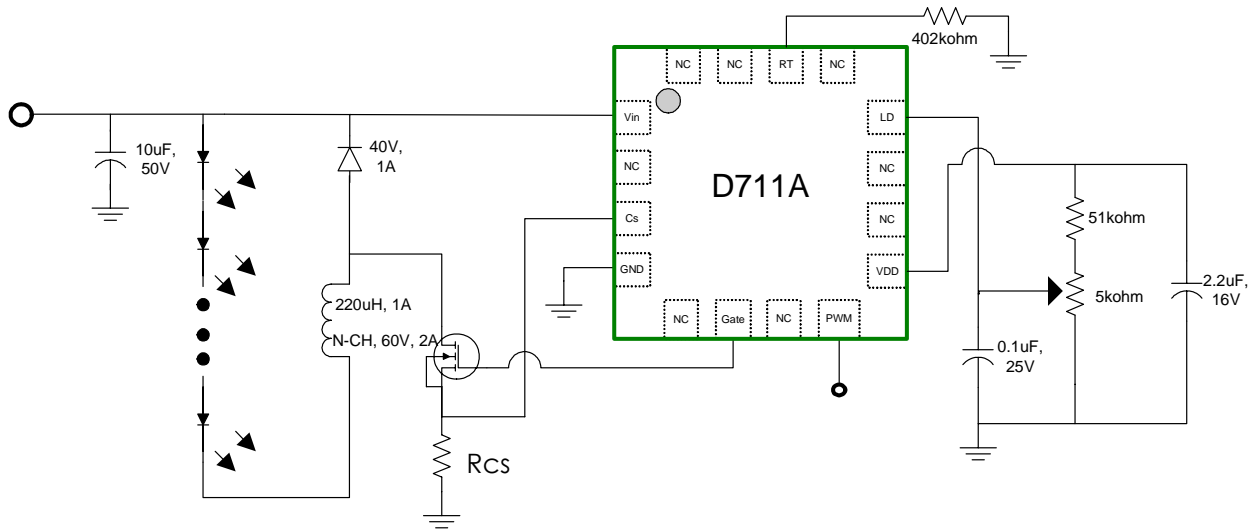


Applications

- General Illumination LED Lighting
- LED Liquid Crystal Displays
- Signage and Decorative LED Lighting
- Automotive

Rogers' dur-E-volt™ D711A LED driver is a high voltage, high-efficiency off-line LED driver designed for LCD panel backlights, billboards, decorative, architectural and other general illumination lighting applications. It is manufactured using a high voltage process and can operate across a wide range of voltages, from 8V to 450V. With this wide input range, the D711A can be used in many diverse High Brightness (HB) LED applications.

Standard Test Circuit



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Absolute Maximum Ratings

Parameter	Symbol	Maximum	Unit	Comments
V _{IN} to GND		-0.5 to +460	V	
V _{OUT} / V _{IN} Ratio		50	%	DC-DC Buck Converter Topology
CS		-0.3 to V _{DD} +0.3	V	
PD, PWM to GND		-0.3 to V _{DD} +0.3	V	
GATE to GND		-0.3 to V _{DD} +0.3	V	
V _{DDMAX}		15	V	
Thermal Resistance, Junction to Ambient	θ_{JA}	40	°C/W	
Power Dissipation		1.8	W	Assumes T _{JMAX} = 125°C, Heat Dissipation = (T _{JMAX} - 50°C) / θ_{JA}
Operating Ambient	T _A	-40 to +85	°C	
Storage Temperature	T _{STG}	-55 to +150	°C	

Note: The above table reflects stress ratings only. Stresses in excess of these ratings can cause permanent damage to the device. Functional operation of the device at these ratings or any other above those indicated in the specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

Pin Description

PIN #	NAME	FUNCTION
1	V _{IN}	Input voltage (8V to 450V)
2	N/C	No Connect
3	CS	LED Current Sense input. Internal current sense threshold is set at 300mV. The external series resistor sets the maximum LED current
4	GND	Device Ground
5	N/C	No Connect, recommend ground
6	GATE	External MOSFET Gate Drive Output
7	N/C	No Connect, recommend ground
8	PWM	Low frequency PWM Dimming Control input with internal pull-down resistor
9	VDD	7.8V regulated supply voltage output. Requires a storage capacitor to ground.
10	N/C	No Connect, recommend ground
11	N/C	No Connect, recommend ground
12	LD	Linear Dimming. Sets the current limit lower than the internal 300mV threshold at the current sense comparator
13	N/C	No Connect, recommend ground
14	R _{OSC}	Resistor to ground sets the oscillator / MOSFET switching frequency.
15	N/C	No Connect, recommend ground
16	N/C	No Connect

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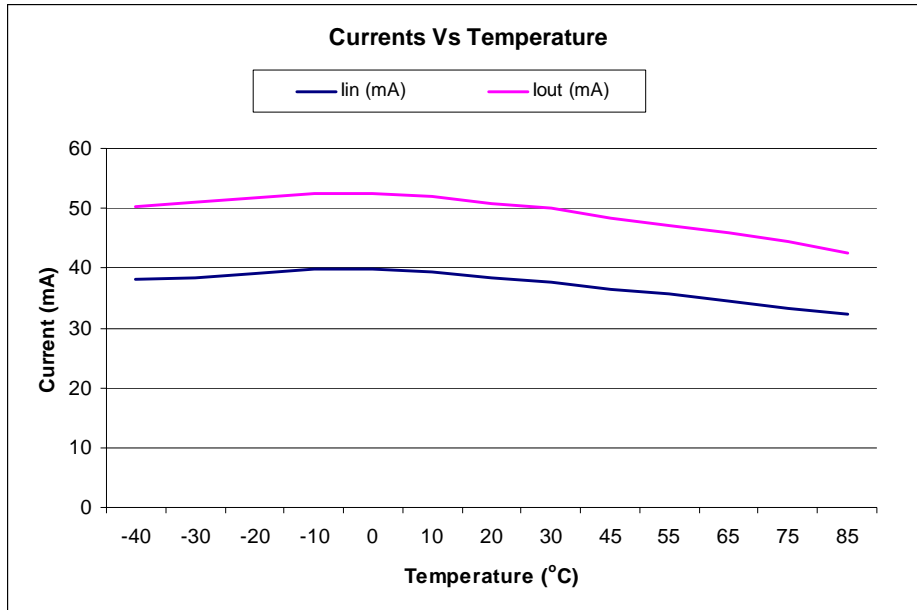
Electrical Characteristics

Parameter	Symbol	Minimum	Typical*	Maximum	Units	Conditions
Input DC Voltage Range	V_{INDC}	8		450	V	DC input Voltage
Shut-Down Mode Supply Current	I_{INsd}			1	mA	PWM to GND $V_{IN}=15\sim 450V$
Internal DC Voltage Regulator	V_{DD}		7.8		V	$V_{IN}=15\sim 450V$, $I_{DD(ext)}=0$, Gate output open
Maximum Voltage To V_{DD} Pin	V_{DDmax}			12	V	External voltage applied to V_{DD} pin
V_{DD} Current Available For External Circuitry	$I_{DD(ext)}$		1.0		mA	V_{IN} =Limited by package power dissipation
PWM Input Low Voltage	PWM_{IL}			0.5	V	$V_{IN}=8\sim 450V$
PWM Input High Voltage	PWM_{IH}	2.4			V	$V_{IN}=8\sim 450V$
PWM Pull-Down Resistance	R_{EN}		135		k Ω	
Current Sense Threshold Voltage	$V_{CS(high)}$		300		mV	
GATE High Output Voltage	$V_{GATE(high)}$		$V_{DD}-0.3$		V	$I_{OUT}=10mA$
GATE Low Output Voltage	$V_{GATE(low)}$		0.3		V	$I_{OUT}=-10mA$
Oscillator Frequency	f_{OSC}		64		kHz	$R_{OSC}=400k\Omega$
Maximum Oscillator PWM Duty Cycle	D_{MAXhf}			85	%	PWM Dimming
Linear Dimming Voltage Range	V_{LD}	0		300	mV	$V_{IN}=15V$
Current Sense Blanking Interval	t_{BLANK}		400		nS	
Delay From CS Trip To GATE Low	t_{DELAY}		300		nS	
GATE Output Rise Time	t_{RISE}		16		nS	
GATE Output Fall Time	t_{FALL}		7		nS	

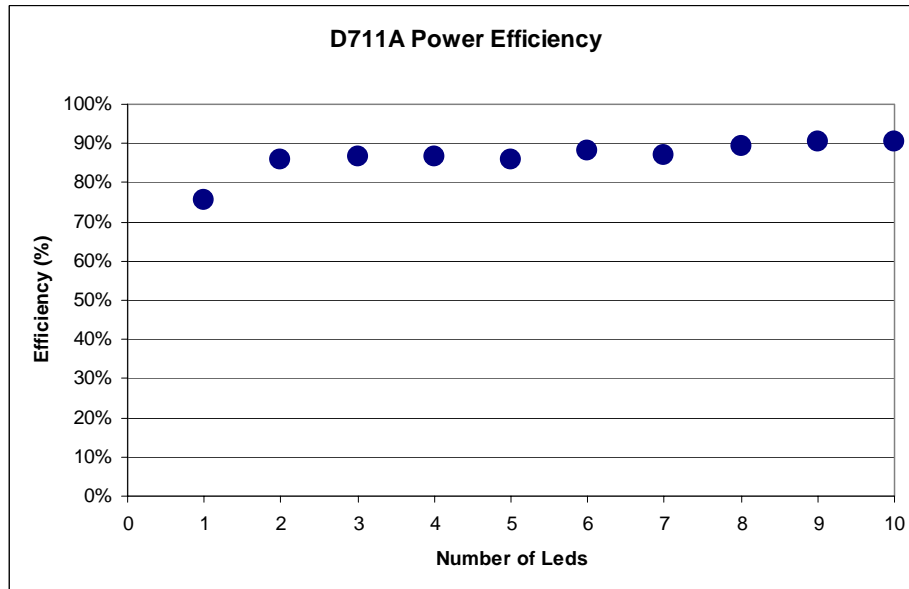
*Typical values should not be used for specification limits. $T_A=25^\circ C$ unless otherwise specified

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Typical Performance Characteristics



$V_{IN}=30V$, $V_{OUT}/V_{IN} = 30\%$, 5 LEDs



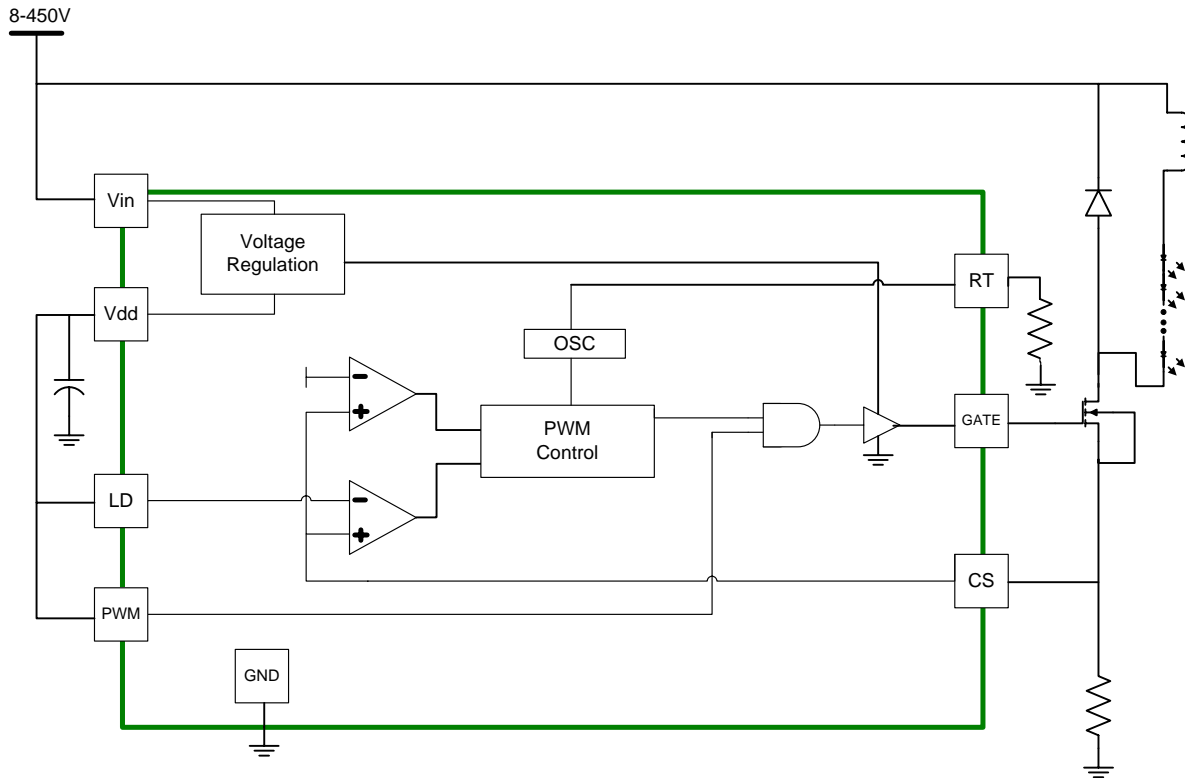
Gate Duty Cycle = 48%, OSRAM Platinum Dragon White LEDs

*Note: Efficiency will vary with LED type/manufacturer.

**Note: Number of LEDs in a circuit will have a direct effect on efficiency and circuit parameters needed to drive them. It is recommended to optimize the driving circuit with the knowledge of which LEDs will be included in the circuit in order to improve overall efficiency.

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Block Diagram of the Driver Circuitry



Theory of Operation

The D711A driver utilizes a high voltage process for a broad input voltage range. This flexibility allows for wide range of operation from either a DC or a rectified AC source. The buck regulator is controlled by a fixed frequency controlling the external MOSFET. The external frequency can easily be tuned using an external resistor. The external feedback current sense is connected to internal comparators. These comparators distribute constant output current to the LEDs. This is essential for maintaining constant luminance across a wide range of LED designs. The LD and PWM pins allow for flexibility to utilize the dimming feature in the D711A. The LD feedback pin is internally connected to a comparator which controls the gate duty cycle. This flexibility allows the user not only to use this pin as a linear dimmer, but can be used to set the regulated LED current.

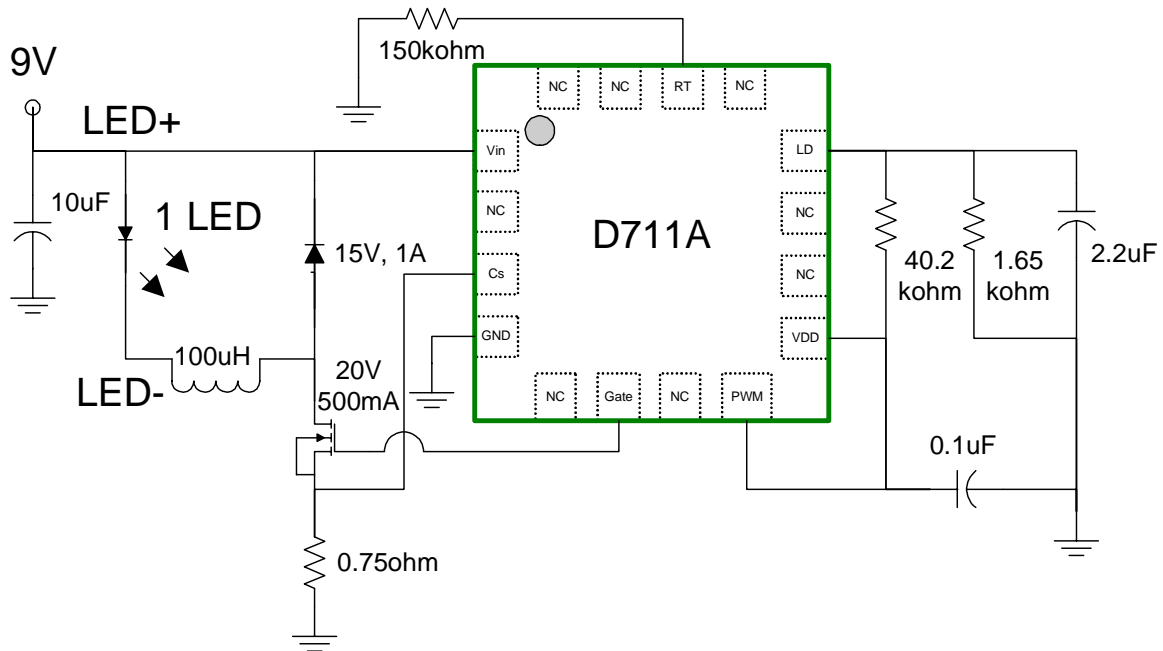
The information contained in this data sheet is intended to assist you in designing with Rogers' LED drivers. It is not intended to and does not create any warranties, express or implied, including any warranty of merchantability or fitness for a particular purpose or that the results shown on the data sheet will be achieved by a user for a particular purpose. The user should determine the suitability of Rogers' LED drivers for each application.

Reference Designs for D711A LED Driver IC

I. Low Voltage Application (non-isolated)

The following circuits represent low voltage applications which can be used to drive a single LED or multiple LEDs. The maximum number of LEDs in a string is dependant on the voltage ratings of the components and LED characteristics.

This circuit is driving a single LED using a 9V source. The LED can be driven at 250mA using the selected resistors R2 and R3 shown below.

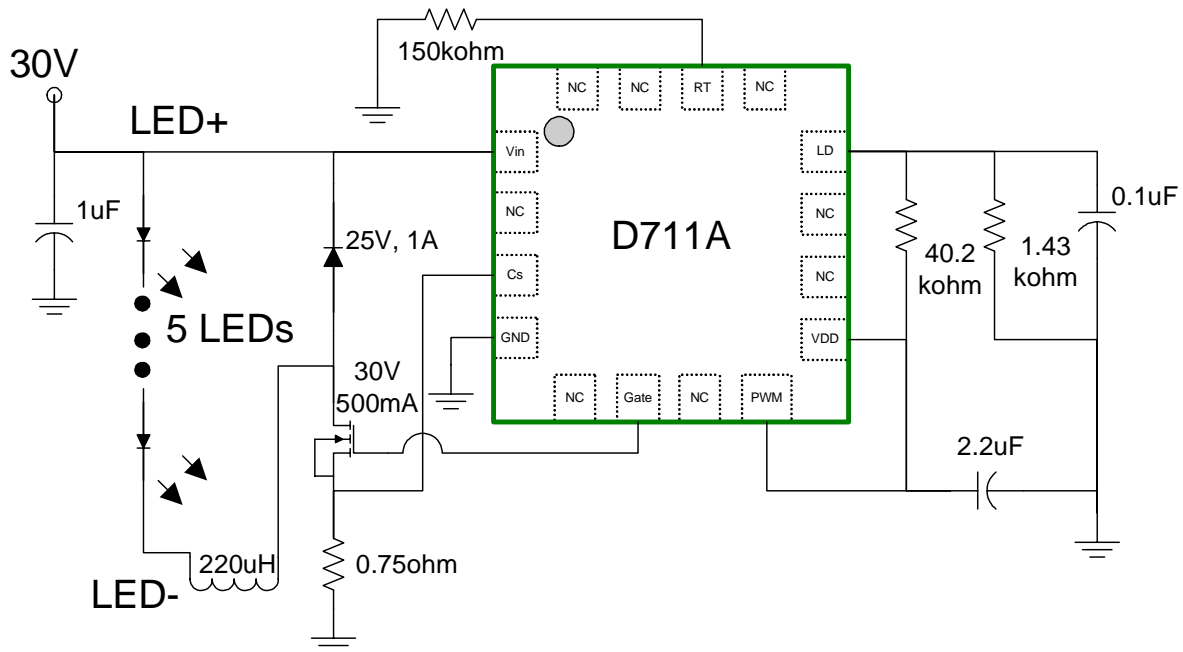


Low Voltage Reference Design Bill of Materials

Component ID	Manufacturer's Part Number	Manufacturer	Description	Package	Qty
D1	MA2YD2100L	Panasonic	Diode Schottky, 15V, 1A	Mini 2P	1
C1	ECJ-4YF1H106Z	Panasonic	Capacitor Ceramic, 10uF, 50V	603	1
LED	W5SM-HYJX-4R9T	Osram	LED White, 3.8W, 3.2V, 350mA		1
L1	LPS6225-104	Coilcraft	Inductor 100uH, 0.52A		1
Q1	SI1012R-T1-E3CT	Vishay	MOSFET N-type, 20V, 500mA	SOT-23	1
Rcs	MCR10EZHLR750	Rohm	Resistor 0.75ohm, 1/4W, 1%	0805	1
RT	P150KLCT	Panasonic	Resistor 150kohm, 1/6W, 1%	0402	1
R2	ERJ-2RKF4022X	Panasonic	40.2kohm, 1/16W, 1%	0402	1
R3	ERJ-2RKF1651X	Panasonic	1.65kohm, 1/16W, 1%	0402	1
C3	C0402C104K8P	Kemet	CAP 0.1uF 10V Ceramic	0402	1
C4	C2012X7R1C225K	TDK	CAP 2.2uF 16V Ceramic	0805	1

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This circuit is driving 5 LEDs in series using a 30V source. The LED can be driven at 250mA using the selected resistors R2 and R3 shown below.



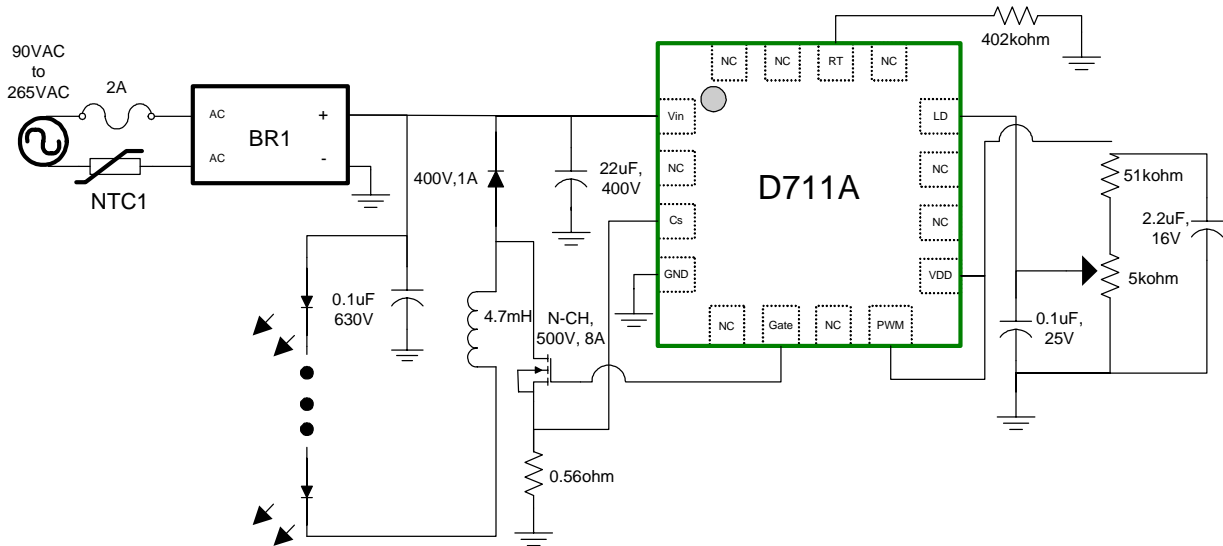
Low Voltage Reference Design Bill of Materials

Component ID	Manufacturer's Par Number	Manufacturer	Description	Package	Qty
D1	MA22D2300L	Panasonic	Diode Schottky, 25V, 1A	Mini 2P	1
C1	ECJ-1VB1E105K	Panasonic	Capacitor Ceramic, 1.0uF, 25V	603	1
LED	W5SM-HYJX-4R9T	Osram	LED White, 3.8W, 3.5V, 350mA		5
L1	MSS1246-224	Coilcraft	Inductor 220uH, 1A		1
Q1	NTR4003NT1G	ON semi	MOSFET N-type, 30V, 500mA	SOT-23	1
Rcs	MCR10EZHF1R750	Rohm	Resistor 0.75ohm, 1/4W, 1%	0805	1
RT	ERJ-6ENF1503V	Panasonic	Resistor 150kohm, 1/8W, 1%	0805	1
R2	ERJ-2RKF4022X	Panasonic	40.2kohm, 1/16W, 1%	0402	1
R3	ERJ-2RKF1431X	Panasonic	1.43kohm, 1/16W, 1%	0402	1
C3	ECJ-2FF1E225Z	Rohm	CAP 2.2uF 25V Ceramic	0805	1
C4	ECJ-2VB1E104K	Rohm	CAP .1uF 25V Ceramic	0805	1

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II. High Voltage Application (non-isolated)

The following circuit represents a high voltage application which can be used to drive from 15 to 42 LEDs depending on the input voltage.



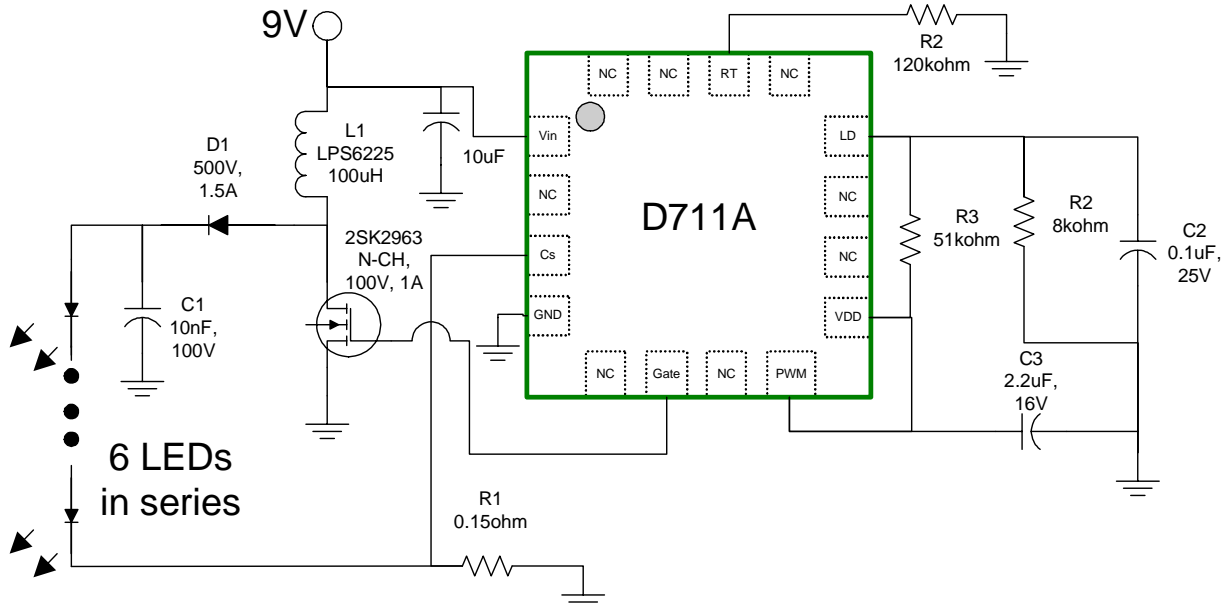
High Voltage Reference Design Bill of Materials

Component ID	Manufacturer Number	Manufacturer	Description	Package	Qty
F1	37312000410	Littelfuse	AC input Fuse	Leaded	1
NTC1	CL-130	GE Sensing	In rush limiter	Leaded	1
BR1	DF04S	Fairchild	Bridge Rectifier	4-SDIP	1
C1	EEV-EB2W220M	Panasonic	22uF, 450V electrolytic capacitor, SMT	Leaded	1
C2	ECJ-2VB1E104K	Panasonic	0.1uF, 25V ceramic capacitor	0805	1
C3	PCC2231CT-ND	Panasonic	2.2uF, 16V ceramic capacitor	0805	1
C4	2222 383 20104	Vishay	0.1uF, 630V Polypropylene Capapcitor	Leaded	1
L1	PCH-45-475	Coilcraft	4.7mH, 0.4A Inductor	Leaded	1
Q1	IRF840ASPBF	Vishay	500V, 8A D2PAK MOSFET	D2PAK	1
D1	RS2J-13-F	Diodes Inc.	600V, 1.5A Fast - soft recovery diode	DO-214AA	1
RA1	PVG5A502C01R00	Murata	Top adjust 5kohm trim pot	Leaded	1
R1	ERJ-8RQFR56V	Panasonic	0.56ohm, 1%, 1/4W resistor	1206	1
RT	ERJ-3EKF4023V	Panasonic	402kohm, 1/8W resistor	0805	1
R3	MCR10EZH5102	Rohm	51 kohm, 1/8W resistor	0805	1

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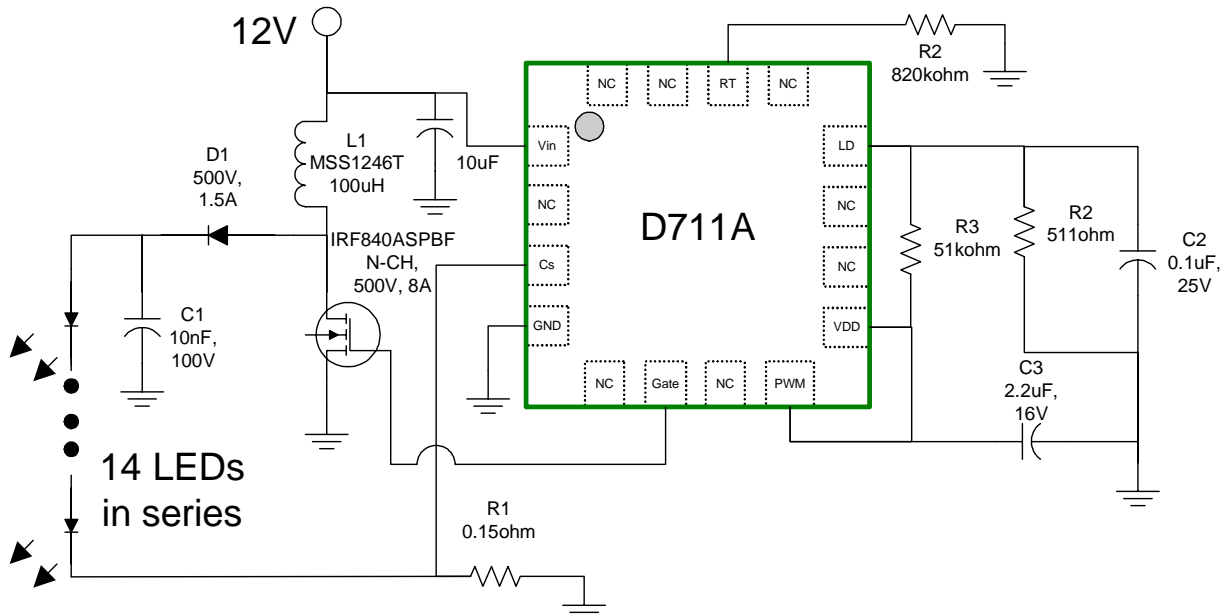
III. 9V Boost Application (Laptop Monitors)

A laptop display backlight application requires several high bright LEDs. The following circuit uses the D711A in boost topology and a 9V supply to drive 6 serial LEDs at 150mA. The circuit can be optimized to drive the LEDs at a different current or drive additional serial LEDs as desired. Driving the LEDs in series maintains luminance throughout all LEDs without the need for current balance resistors or LED sorting.



IV. 12V Boost Application (Automotive)

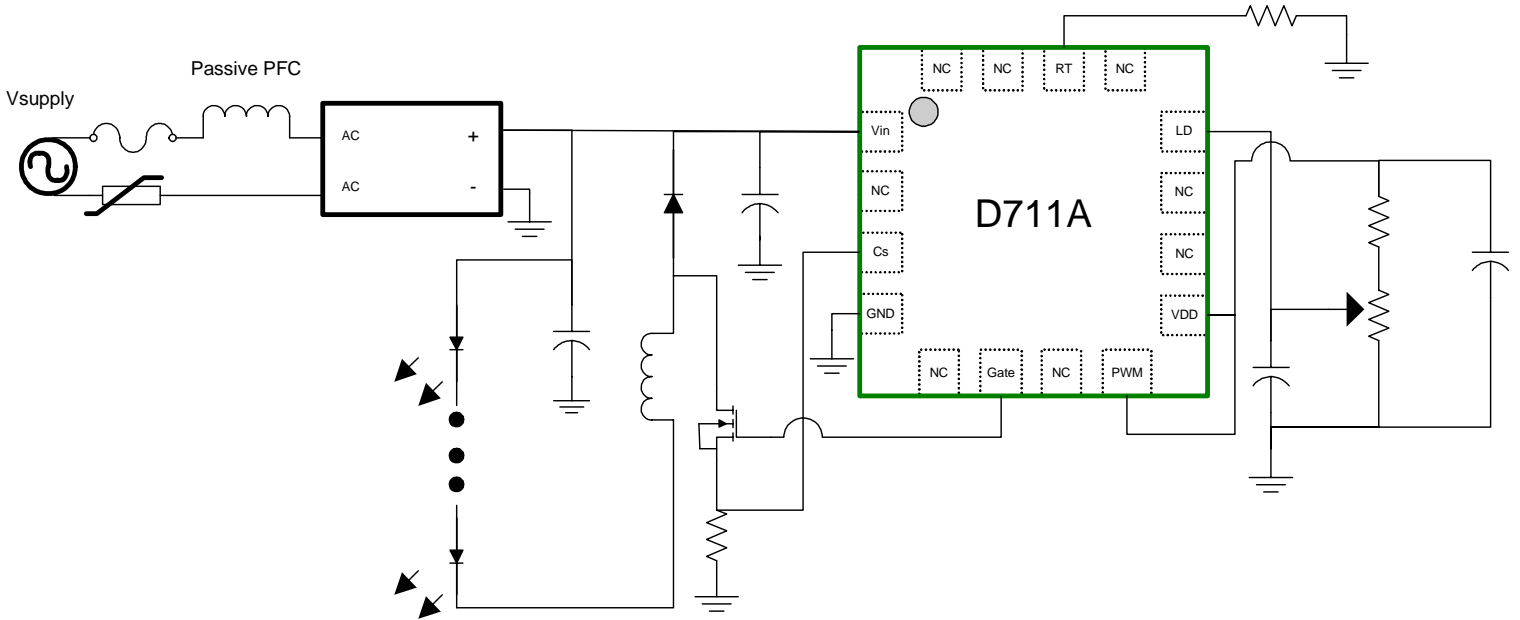
The following circuit uses the D711A in boost topology and a 12V supply to drive 14 serial LEDs at 150mA. The circuit can be optimized to drive the LEDs at different currents or drive additional serial LEDs as desired.



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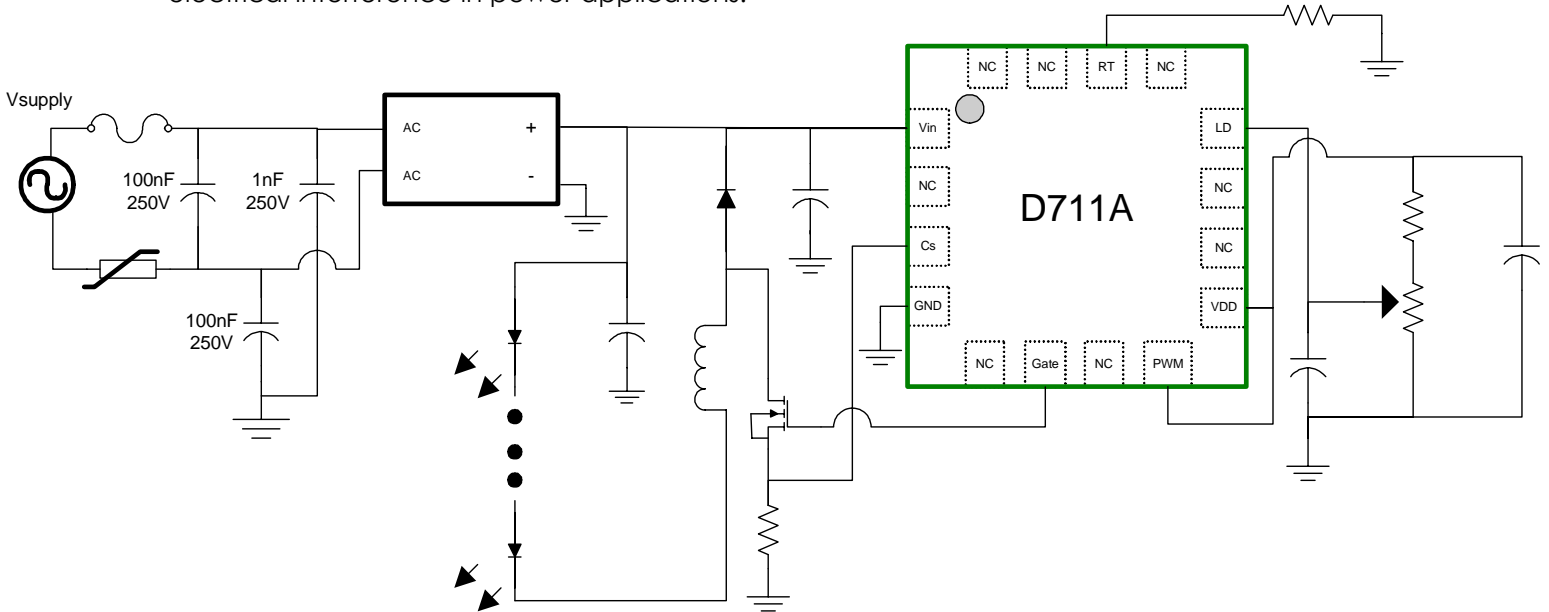
V. Passive Power Factor Correction

The following circuit shows how to use passive power factor conversion with the D711A. By placing an inductor between the voltage source and the full bridge rectifier, an increase in power factor can be achieved. High inductance values such as 100mH will result in better PFC. However, LED current will be limited by current rating of the inductor and the supply current.



VI. EMI Filter

The following circuit uses decoupling capacitors as an EMI filter with the D711A to minimize electrical interference in power applications.



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Designing With A D711A LED Driver IC

The D711A uses a buck converter topology also known as a Step-Down DC to DC converter. As a switched mode power supply it is important to know that the MOSFET must not be driven at more than 50% Positive Duty Cycle. This is why the driver requires twice the LED forward voltage for proper operation. The extra voltage on the input will be converted to more current for driving the LEDs. The current ($I_{O,MAX}$) going through the LEDs will be much greater than the current draw from the whole system (I_{Input}). Therefore, designing with the D711A driver is essential for reducing the power consumption of your application.

In order to choose the proper components and values for use with the D711A, you must first know the specifications of the LEDs which are going into your application. Based on the forward voltage (V_F), forward current (I_F), topology, and number of LEDs you can determine the minimum input voltage and minimum output current. These will be used in determining the remaining components.

For example, given the following you can determine V_{Input} and $I_{O,MIN}$:

$V_F = 3.5V$
 $I_F = 350mA$
 Topology = 1 string of 2 LEDs (series configuration)

$V_{Input} = (\text{Number of Serial LEDs} \times \frac{V_{LED}}{Duty})$ where V_{LED} is the sum off all the V_F of the LEDs in series. The max duty cycle is 50%.

$$V_{Input} = 1 \times \frac{3.5 + 3.5}{0.5} = 14V$$

The LEDs will need at least 14V to drive. The minimum input voltage for the D711A LED driver is 8V. For this example we will use 15V DC, which is more common in systems.

$$V_{Input} = 15V$$

$$I_O = (\text{Number of Strings} \times I_F) = 1 \times 350 = 350mA$$

Based on these results we can now choose the remaining components.

i. Choose Diode D_1

The diode chosen for D_1 needs to fill 2 requirements, $V_{IN,MAX}$ and $I_{O,MAX}$. as defined below

$$V_{IN,MAX} = 1.5 \times V_{Input} = 1.5 \times 15 = 22.5V$$

The average current through the diode will be

$$I_{O,MAX} = I_O = 350mA$$

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Based on these calculations we see that a 25V, 1A ultra fast diode will handle the job.

ii. Choose Switching Frequency

Switching frequency plays a critical role in determining the efficiency of the system. Higher switching frequencies will allow for the use of a smaller inductor. The trade off is lower efficiency due to increased MOSFET switching losses. Typical switching frequencies are in the range of 20 KHz – 200 kHz. For this example we will choose 158 kHz. The D711A kit boards are equipped to run at 50 kHz.

Switching power losses can be quantified by using the following Ideal equation.

$$P_{SW} = \frac{V_{FET} \times I_O \times (t_{Rise} + t_{Fall})}{2 \times T_{Period}}$$

iii. Set R_T to meet switching frequency

The internal oscillator is set by comparing the voltage present at the RT pin. Increasing the resistance at this pin will decrease the switching frequency of the MOSFET. The equation below can be used to choose an appropriate value for R_T .

$$F_{OSC} = \frac{30000}{R_T + 40} = \frac{30000}{150K\Omega + 40} = \frac{30000}{190} = 158KHz$$

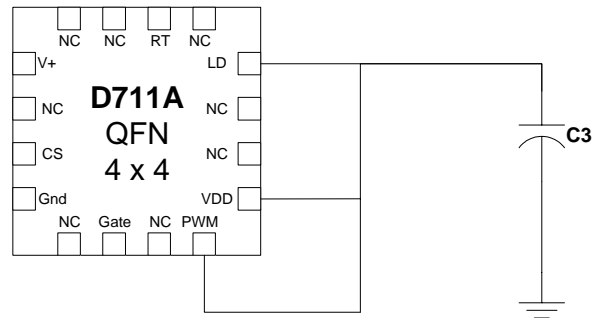
iv. Select Current Sensing Resistor R_{CS}

The resistor value placed at R_{CS} will determine the maximum amount of current through the LEDs ($I_{O,MAX}$).

$$R_{CS} = \frac{V_{REF}}{1.15 \times I_{O,MAX}} = \frac{0.3}{1.15 \times 0.35} = 0.75\Omega$$

Choosing a resistor with a slightly larger resistance will make the circuit incapable of reaching the target $I_{O,MAX}$. Reducing the resistance will allow more current to flow, which can be compensated by reducing the Positive Duty Cycle to reach the target $I_{O,MAX}$.

If dimming is not required, then the external tuning components can be removed from the circuit by selecting the correct R_{CS} resistor to keep the LEDs from going over max current. The VDD, LD, & PWM pins can all be shorted together and attached to a charge capacitor.



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v. Choose Inductor

The inductor has a direct relationship with the voltage overhead ($V_{input} - V_{led}$) and the charge time, while being inversely related to the LED current. A higher LED current will need a smaller inductor. However, physically smaller inductors typically have lower saturation current rating.

The following equations can be very helpful when choosing an inductor. If your application specifies an inductor already, the equation can be rearranged to specify what would be necessary to run your application with that inductor. Our D711A kit boards come equipped with a 220uH inductor. The equation was then rearranged to calculate what duty cycle would be needed to achieve the same output current. It was determined that a 45% duty cycle would provide the appropriate output current.

To calculate the charge time, use the following equation.

$$T_{on} = \frac{\text{PositiveDutyCycle}}{F_{osc}} = \frac{0.45}{158\text{khz}} = 2.8\mu\text{s}$$

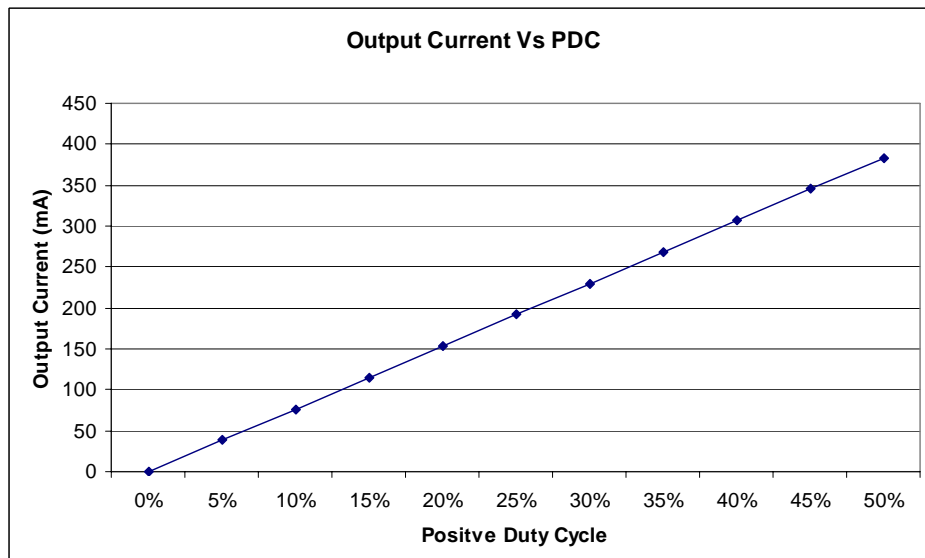
Now calculate the inductance required using the charge time.

$$L = \frac{(V_{Input} - V_{LED}) \times T_{ON}}{0.3 \times I_{O,MAX}} = \frac{(15 - 7) \times 2.8\mu}{0.3 \times 0.35} = 217\mu\text{H}$$

For this example we will choose a 220μH inductor. It is also important that the saturation current of the inductor is capable of handling the LED current.

$$I_{InductorSaturation} > I_{O,MAX}$$

The following graph illustrates the linear relationship between the output current and the Positive Duty Cycle driving the MOSFET. Maximum output current can be reached at 50% PDC.



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vi. Select Switching MOSFET

The MOSFET should be chosen such that the breakdown voltage is greater than the maximum input voltage for the LED circuit.

Note: This voltage is the same as V_{Diode} Peak voltage $\geq V_{IN,MAX}$

$$V_{MOSFET} = V_{Diode} = 1.5 \times V_{IN,MAX} = 1.5 \times 15 = 22.5V$$

Current rating for the MOSFET can be selected to match the maximum current through the LEDs ($I_{O,MAX}$). A MOSFET with a lower current rating may be selected if driving the MOSFET at much lower duty cycles than 50%. The following equation can be used to find the maximum current through the MOSFET for this case.

$$I_{MOSFET} = \sqrt{PDC} \times I_{O,MAX} = \sqrt{0.45} \times 0.350 = 235mA$$

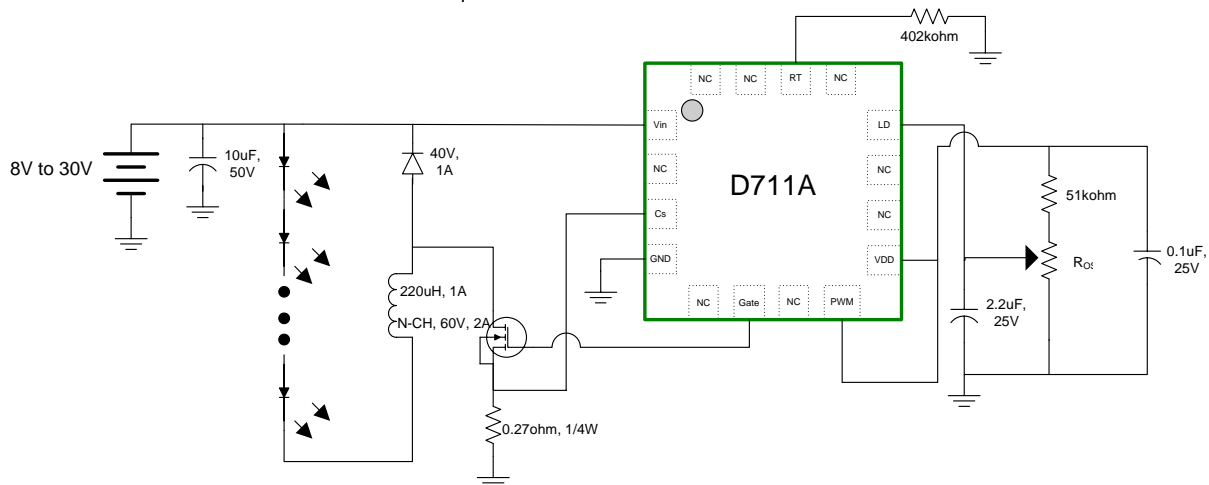
vii. Set Tuning Resistor Values for Threshold Current

The LD pin is used for linear dimming of the LED current. It can also be used to select a specific output current using a pair of resistors. There are 2 methods that can be used to optimize the circuit by selecting a pair of resistors to define a specific threshold current:

1. Attach separate power supply to LD pin.
 - Acquire the LD voltage by using a power supply set to 0V, and then slowly increase the voltage until the desired duty cycle and LED current are reached.
 - Insert the LD voltage into the following equation as V_{LD} to select the appropriate voltage divider ratio.

$$R_1 = \frac{R_2 \times V_{DD}}{V_{LD}} - R_2 = \frac{R_2 \times 8V}{V_{LD}} - R_2$$

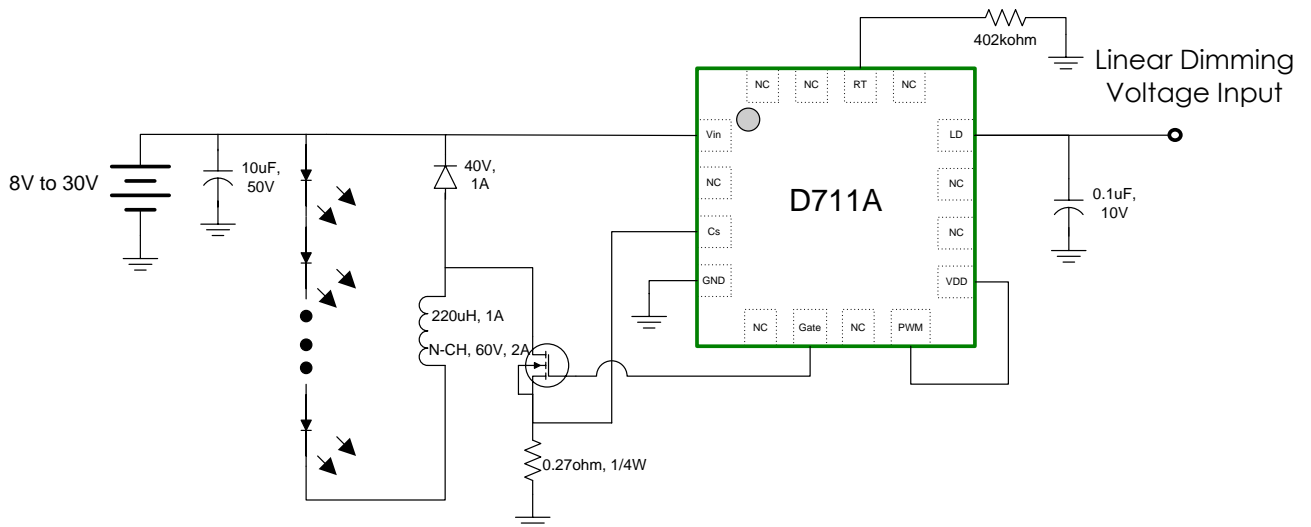
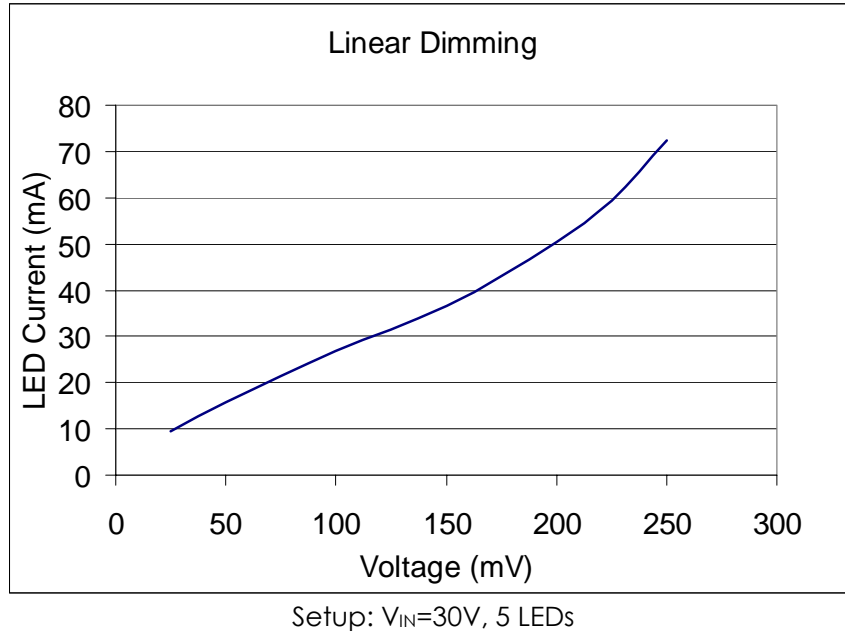
2. Attach a potentiometer and a 51KΩ resistor in series as shown in the schematic below.
 - Adjust the potentiometer until the desired duty cycle and LED current are reached.
 - Measure the resistance of the potentiometer, and then replace it with an equivalent resistor.



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VII. Linear Dimming

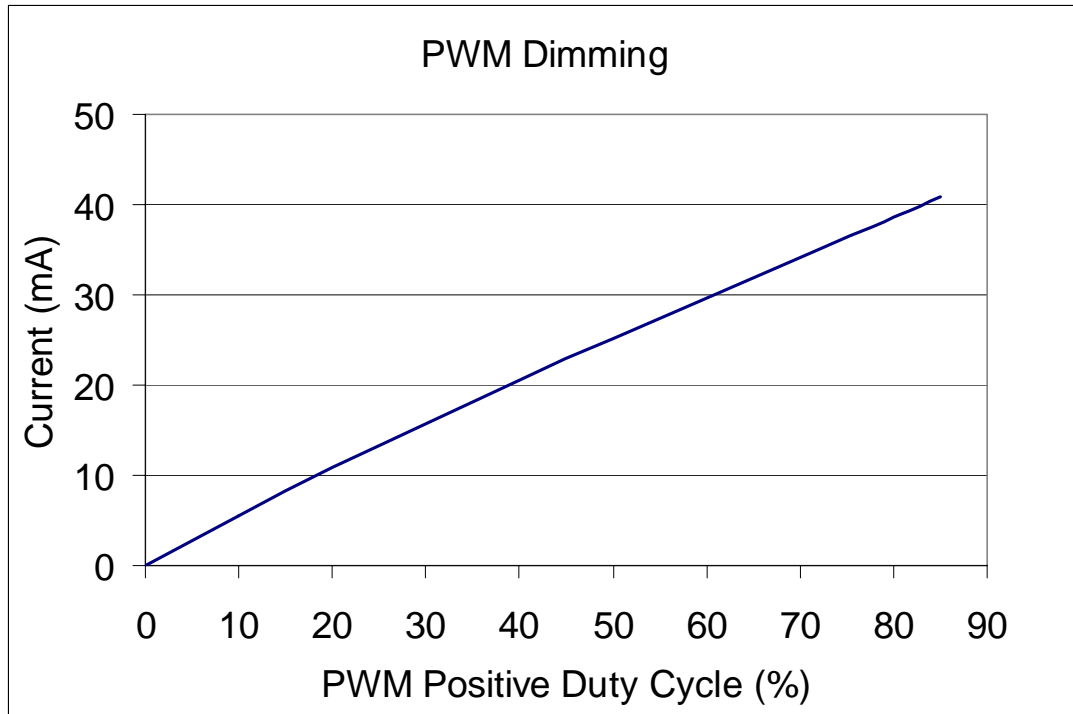
Dimming can be achieved by varying the DC voltage on the linear dimming pin from 0~300mV. The graph below shows the effect on the output luminance. The dimming voltage varies the duty cycle of the gate drive to the MOSFET. Care must be taken to insure that this duty cycle does not exceed 50%. If the duty cycle exceeds 50% the LEDs may be damaged. The circuit below shows a low voltage application with linear dimming that can be used to drive up to 5 LEDs.



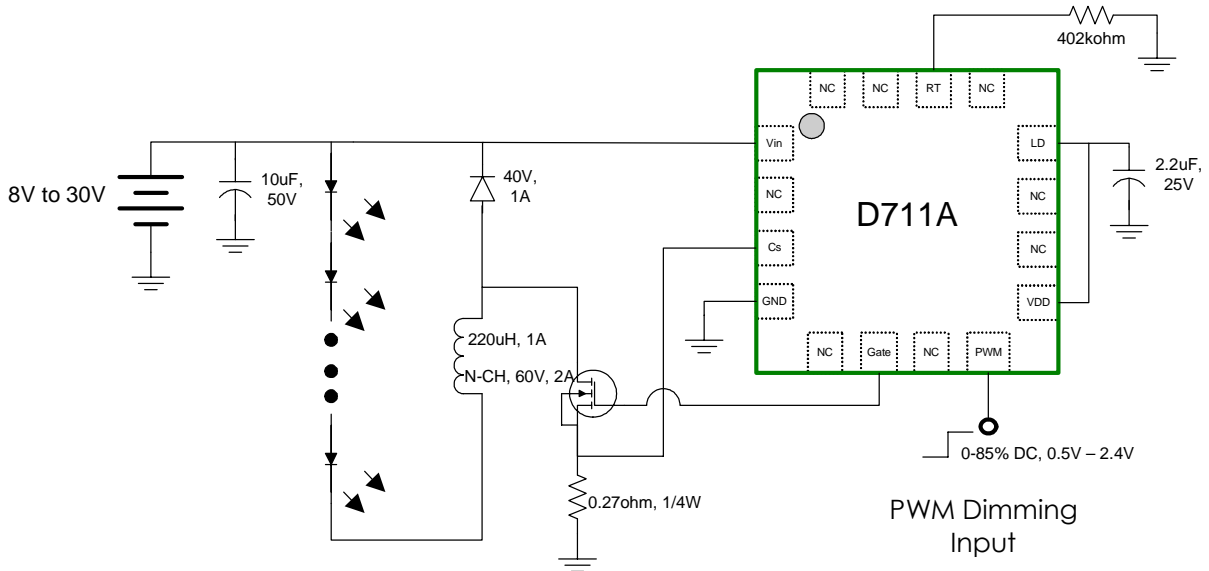
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VIII. PWM Dimming

Dimming is also possible by applying a PWM signal ranging from 0~85% to the PWM pin. The PWM signal must follow the specification shown in the electrical characteristics table on page 3. The threshold current must be set according to the process shown in section II.vii. The circuit below shows a low voltage application with PWM dimming that can be used to drive up to 5 LEDs.



Setup: $V_{IN}=30V$, 5 LEDs



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Solder Re-Flow Recommendations

Classification Reflow Profiles

Profile Feature	Pb-Free Assembly 1DDD711AA-P02
Average ramp-up rate (T_L to T_P)	3°C/second max.
Preheat -Temperature Min (T_{Smin}) -Temperature Max (T_{Smax}) -Time (min to max) (t_s)	150°C 200°C 60-180 seconds
T_{Smax} to T_L -Ramp-up Rate	3°C/second max.
Time maintained above: Temperature (T_L) -Time (T_L)	217°C 60-150 seconds
Peak Temperature (T_P)	250 +0/-5°C
Time within 5°C of actual Peak Temperature (T_P)	20-40 seconds
Ramp-down Rate Time 25°C to Peak	6°C/second max.
Temperature	8 minutes max.

IPC/JEDEC J-STD-020B

July 2002

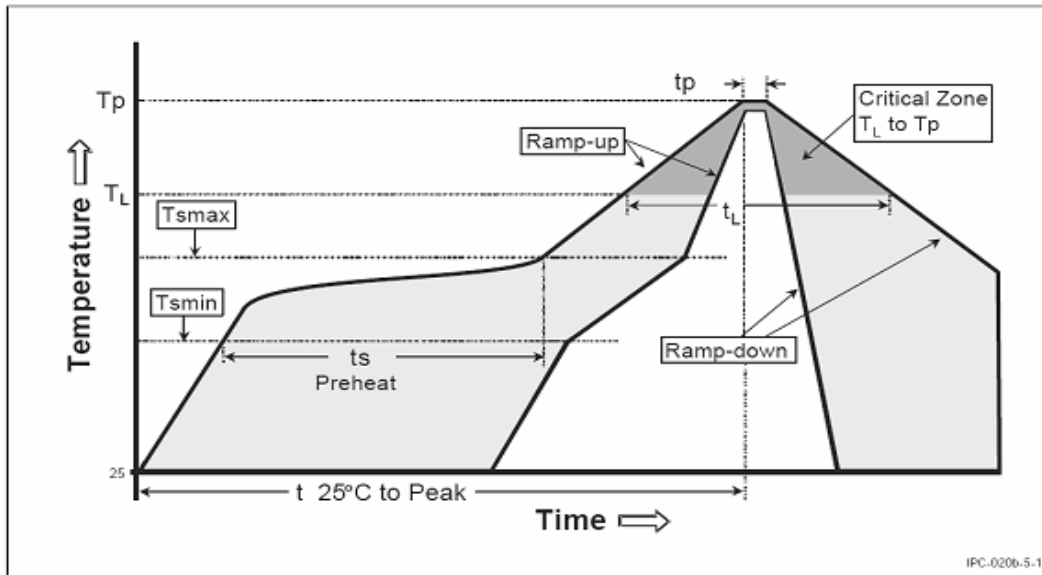


Figure 5-1 Classification Reflow Profile

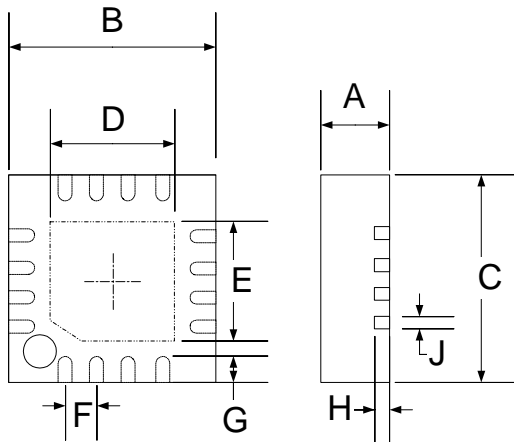
Note: All Temperatures refer to topside of the package, measured on the package body surface

Note: All Temperatures refer to IPC/JEDEC J-STD-020B

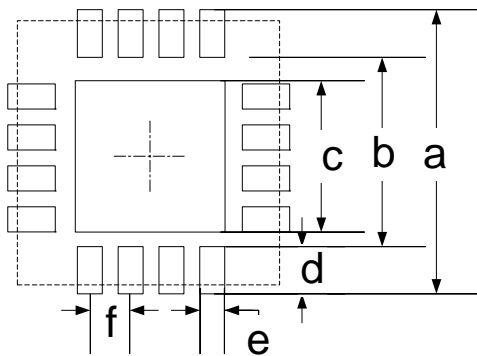
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Ordering Information

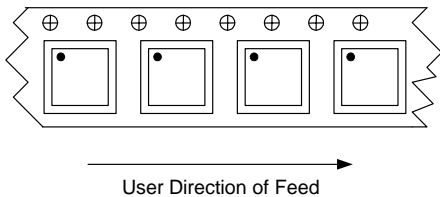
The D711A LED driver IC is available in a Pb-free green QFN-16 package in tape and reel. Rogers' engineers also provide full support to customers, including specialized circuit optimization and application retrofits.



	QFN-16 Dimensions					
	Min		Typical		Max	
	mm	in	mm	in	mm	in
A	0.70	0.028	0.75	0.030	0.8	0.031
B	3.925	0.155	4.00	0.157	4.075	0.160
C	3.925	0.155	4.00	0.157	4.075	0.160
D	2.25	0.089	2.30	0.091	2.35	0.093
E	2.25	0.089	2.30	0.091	2.35	0.093
F			0.65	0.026		0.000
G	0.35	0.014	0.55	0.022	0.75	0.030
H			0.20	0.008		0.000
J	0.25	0.010	0.30	0.012	0.35	0.014

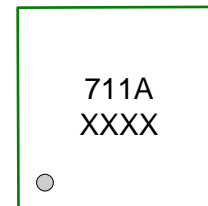


	QFN-16 Pad Layout					
	Min		Typical		Max	
	mm	in	mm	in	mm	in
a	4.30	0.169	4.35	0.171	4.40	0.173
b	2.85	0.112	2.90	0.114	2.95	0.116
c	2.10	0.083	2.15	0.085	2.20	0.0866
d	0.67	0.026	0.72	0.028	0.77	0.030
e	0.25	0.010	0.30	0.012	0.35	0.014
f			0.65	0.026		



DFN: Embossed tape on 360mm diameter reel. 2000 units per reel.
PN: 1DDD711AA-P02

QFN-16 Lead Free
1DDD711AA-P02



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ISO 9001:2000, ISO/TS 16949:2002, and ISO 14001:1996 Certified

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