MAP9010

Application Note

Introduction

MAP901X series is designed to connect directly to an AC source via 2 wires like MAP900X series. The MAP901X achieves high power factor, typically 0.95 to 0.99 MAP901X is highly integrated; the driver circuit and the LED modules can be mounted on the same board, greatly reducing the cost and size of the LED light bulb. Also the MAP901X has a smaller Input power variation (typ7%).

The special function that has a MAP901X series as compared to MAP900X is triac-dimming function and analog dimming function.

Basic Operation

Figure 1 shows a typical application circuit for the MAP901X series. If you want to use as AC-direct mode (Analog dimming function) of MAP9010, has to MODE pin is connect to GND. Each LED group is turned-on by exceeding LED V_F. As the line voltage changes, each LED group turns-on in regular sequence, the sequence may be changed by changing the LED group arrangement.

Each set of LEDs is turned-on form Group #1 to Group #4 and the output current is set by sensing pin resistor. The voltage at the CS Pin, which is negative with respect

If the line voltage is over V_F of LED group #1, LED group #1 is turned-on and the programmed LED current flows in LED group #1. All the currents of LED Group #1 to #4 are limited by the MAP901X series circuit.

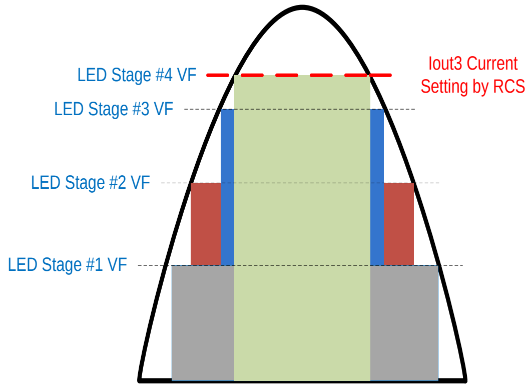


Figure 2. Basic Operation

Adjustable Power by R_{SENSE}

The current drawn by the LED stages is programmed by the R_{SENSE} resistor, to increase power rating you have to reduce sensing resistor resistance. If RCS value be increased, channel current would be decreased because MAP901X's current sensing method is negative sensing.

Once determined RCS value, the Iout3 current is fixed by as below formula.

$$I_{HOLD} = 191mA \times \frac{6.8ohm}{R_{CS}}$$

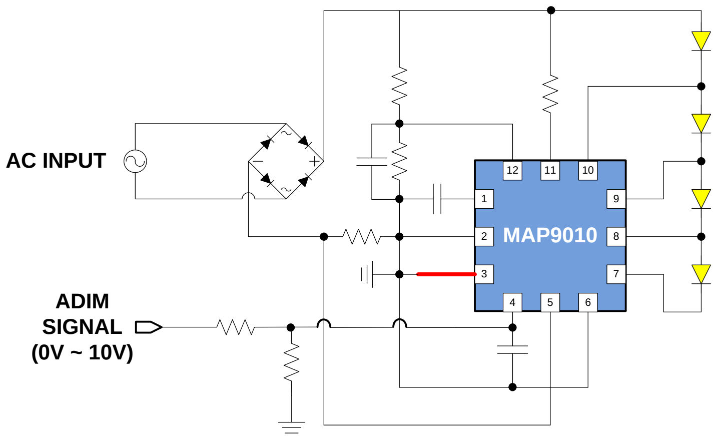


Figure 1. Typical Application Circuit in AC-direct Mode

And reference current of other pins determined by Iout3 as below rate;

$$I_{OUT3}:I_{OUT2}:I_{OUT1}:I_{OUT0} = 1 : 0.82 : 0.65 : 0.44$$

So If Rcs value is 6.8ohm, IOUT3 current is

$$IOUT_3 = 191mA \times \frac{6.8ohm}{6.8ohm} = 191mA$$
$$IOUT_2 = 191mA \times 0.82 = 156mA$$
$$IOUT_1 = 191mA \times 0.65 = 126mA$$
$$IOUT_0 = 191mA \times 0.44 = 85.2mA$$

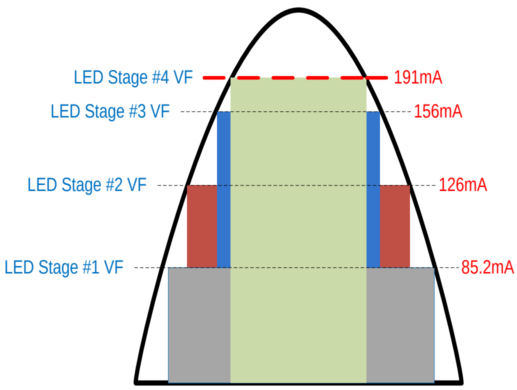


Figure 3. Each current value by RCS

Internal reference for performance

MAP901X's IOUT1,2 generated sine wave references by detect line voltage sensing.

If there is no line sensing, the LED current like figure 3. But application circuit of MAP9010 have to applied line sensing to other function, so normal LED current as below.

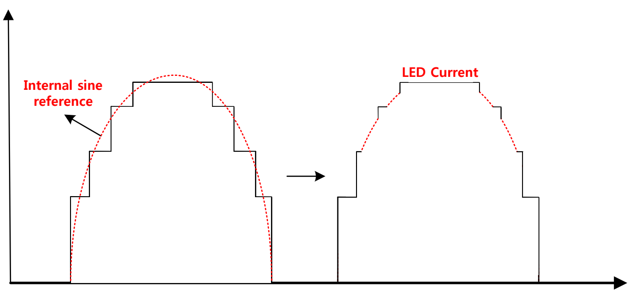


Figure 4. LED current applied internal reference

As applied internal reference function, THD,PF light efficiency will be improved.

Improved Current variation

MAP901X series current accuracy is enhanced through the internal line regulation function. In AC-Direct solution, current variation is large because as input voltage rises output current also increases in proportion as below.

Once input voltage rises, the LED turn-on time rises and total LED current area is increases. This is shown as Fig 4.In this feature as the input voltage is increased, the IC and LED temperature also raise. This reduces LED and IC life time

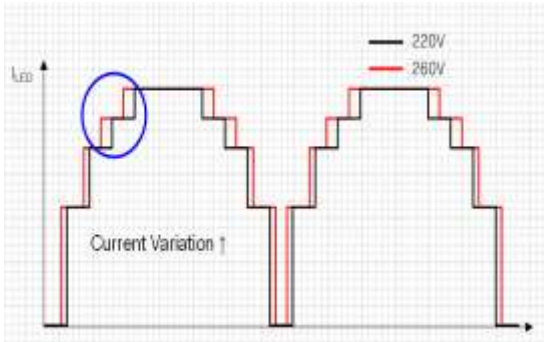


Figure 5. Normally AC-Direct LED current

In the MAP901X series LED output current decreases as the input voltage increases through the action of the internal compensation circuit. So even if input line voltage is increased, the LED current is not increased

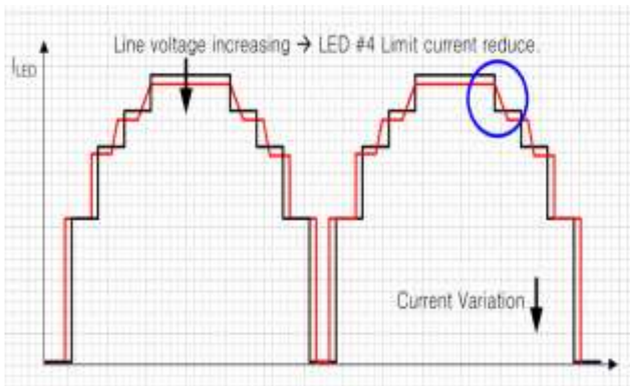


Figure 6. MAP901X's LED Current

Increasing input voltage is sensed by the MAP9000 Rhold pin, which reduces the set current of LED group #4.

Set R_{LINE} Resistance

R_{LINE} pin senses the input voltage by the R_{LINE} potential divider, R1 & R2. Line-sensing voltage is necessary to line regulation function and triac-dimming function and Over-Voltage Protection(OVP). The maximum voltage that can be applied to the MAP9010 R_{LINE} pin is 20V.

MAP9010 can perform line regulation when input voltage is changed. This function means that MAP9010 performs limiting output current when input voltage is changed. It is detected by using R_{LINE} pin voltage. So according to R_{LINE} resistance, analog dimming performance and OVP detection voltage are changed in AC-direct operation (MODE pin=GND). The analog dimming performance is as below according to changing R_{LINE} resistance.

1. RDIM function in 220V Application

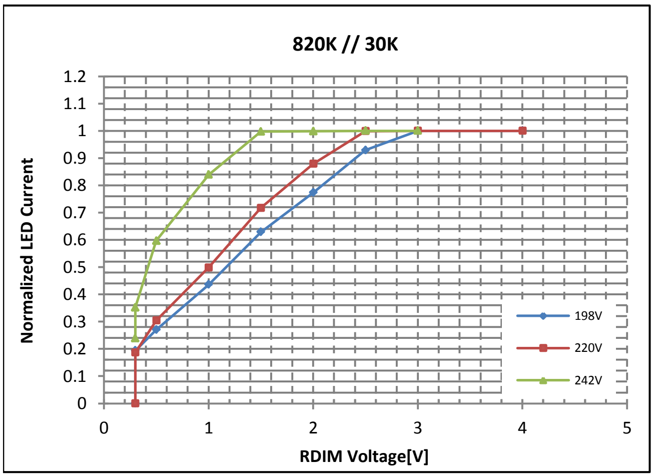


Figure 7. 820K / 30K in 220V Application

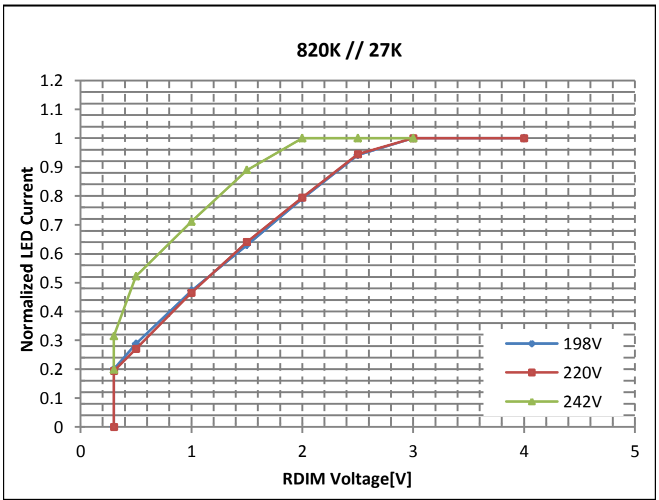


Figure 8. 820K / 27K in 220V Application

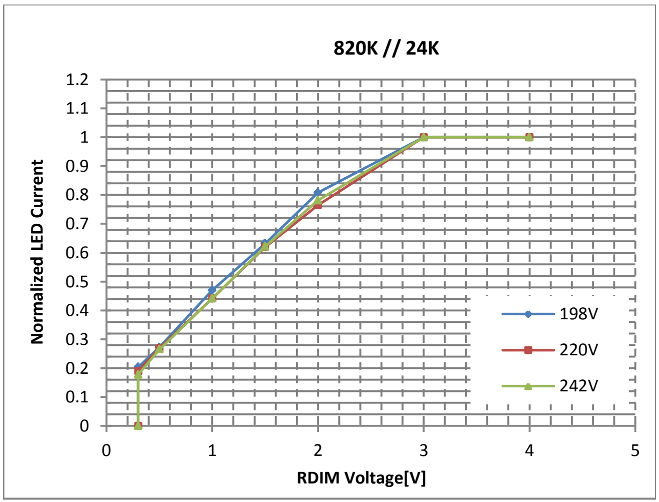


Figure 9. 820K / 24K in 220V Application

The OVP detection voltage is also change according to R_{LINE} resistor.

R_{LINE} Divide Resistor		Input OVP Voltage
R1	R2	
820K	30K	272V
820K	27K	299V
820K	24K	Over 300V

The optimized resistance value to get a best performance of line regulation is as below,

Test Item(220V)		Input Power [W]	Power Variation	Input current [mA]	OVP protection
Rline resistor	Input Voltage	AC-Direct Mode (Mode Pin=GND)			
820KΩ // 33KΩ	198V	15.840	-10.51%	80.000	251V
	220V	17.700	0.00%	80.600	
	242V	17.200	-2.82%	71.590	
820KΩ // 30KΩ	198V	16.550	-0.66%	83.700	272V
	220V	16.660	0.00%	76.500	
	242V	15.670	-5.94%	65.800	
820KΩ // 27KΩ	198V	16.530	-11.93%	83.400	299V
	220V	18.770	0.00%	85.400	
	242V	18.710	-0.32%	78.200	
820KΩ // 24KΩ	198V	12.070	-13.72%	61.300	Over 300V
	220V	13.990	0.00%	64.000	
	242V	15.650	11.87%	65.100	

2. RDIM Function in 120V Application

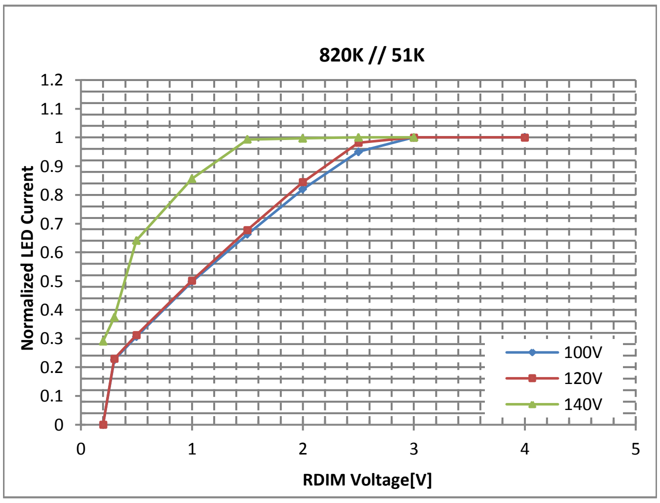


Figure 10. 820K / 51K in 120V Application

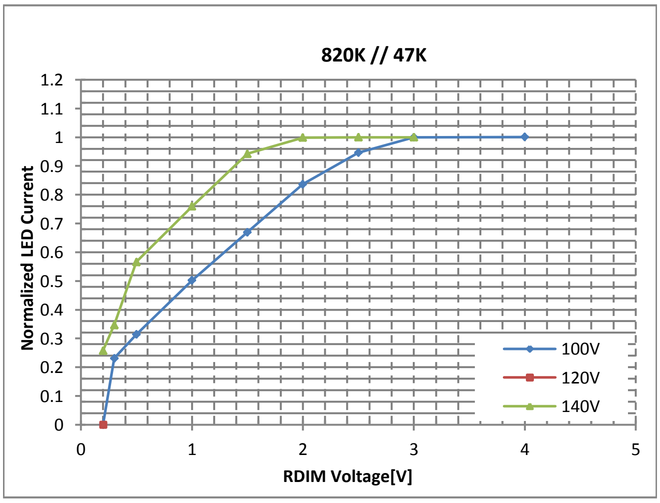


Figure 11. 820K / 47K in 120V Application

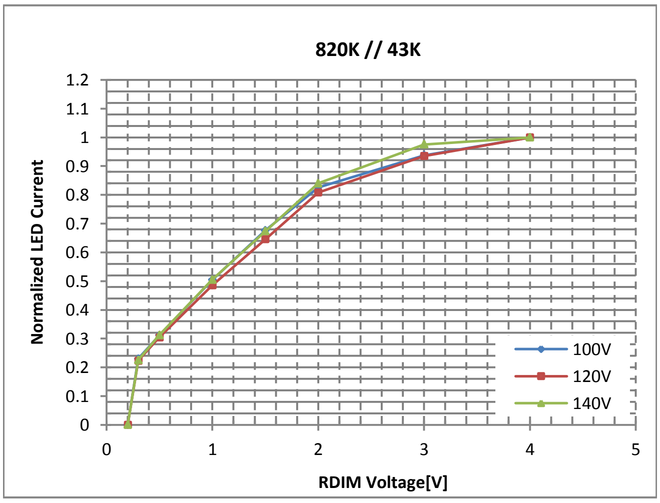


Figure12. 820K / 43K in 120V Application

The OVP detection voltage is also changed according to R_{LINE} resistor.

R_{LINE} Divide Resistor		Input OVP Voltage
R1	R2	
820K	51K	272V
820K	47K	299V
820K	43K	Over 300V

The optimized resistance value to get a best performance of line regulation is as below,

Test Item(120V)		Input Power [W]	Power Variation	Input current [mA]	OVP protection
Rline resistor	Input Voltage	AC-Direct Mode (Mode Pin=GND)			
820KΩ // 56KΩ	100V	10.34	-13.26%	104.2	150V
	120V	11.92	0.00%	100.15	
	140V	9.94	-16.61%	72.1	
820KΩ // 51KΩ	100V	12.12	-23.48%	121.5	166V
	120V	15.84	0.00%	132.3	
	140V	14.90	-5.93%	107.4	
820KΩ // 47KΩ	100V	11.47	-26.71%	115.2	180V
	120V	15.65	0.00%	130.6	
	140V	16.33	4.35%	117.8	
820KΩ // 43KΩ	100V	11.32	-27.11%	113.8	195V
	120V	15.53	0.00%	129.8	
	140V	18.08	16.42%	129.9	

Typically, recommended voltage range is 10% of reference voltage. The range of 120V model is 100V to 140V and 220V model is 200V to 260V. If a high input line voltage is applied the R_{LINE} pin voltage has to be below its maximum rating. In this design, 120V R1/R2 is 820 kΩ / 56KΩ and 220V R1/R2 are 820 kΩ / 30 kΩ.

$$V_{RLINE(MAX)} = V_{AC,RMS(MAX)} \times \frac{R2}{R1+R2}$$
$$= 140V \times 1.414 \times \frac{56K}{820K+56K}$$
$$= 8.9V$$

$$V_{RLINE(MAX)} = V_{AC,RMS(MAX)} \times \frac{R2}{R1+R2}$$
$$= 100V \times 1.414 \times \frac{56K}{820K+56K}$$
$$= 6.4V$$

If you concerned maximum voltage of R_{LINE} resistor, you should consider about R_{LINE} resistor rating.

Triac-dimming function

As LED lighting enters the mainstream of general lighting it is important to be compatible with the existing line dimming infrastructure. Dimmers intended for incandescent bulbs reduce the amount of energy delivered by blocking or cutting away part of the AC waveform. Since incandescent bulbs look like resistive loads, the power delivered is proportional to the relative amount of the full AC waveform allowed to pass. The voltage applied to the bulb is gated on for a particular fraction of each half cycle of the incoming waveform by a triac.

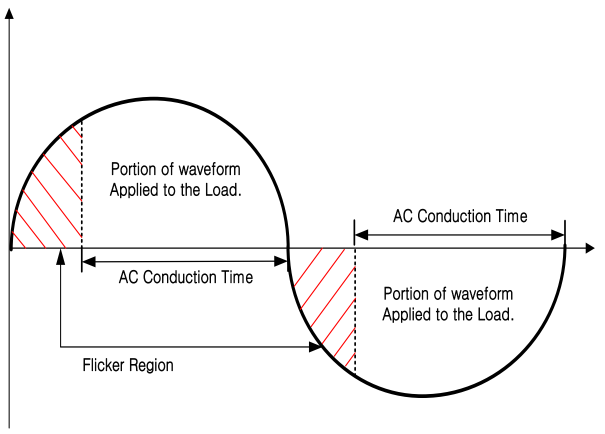


Figure13. Leading Edge Phase Cut Waveform

This is illustrated in Figure 7 and is referred to as the conduction angle when expressed in degrees. 180° represent no phase cutting. The maximum conduction angle varies depending on the dimmer manufacturer, but in most cases it ranges from 120−160°. Decreasing the conduction angle reduces the applied RMS voltage and consequently the amount of power delivered to the bulb.

All Phase control is subject to Flicker because regions of the input current waveforms reach zero. Basically, to apply Triac dimming control to an AC-Direct solution we use a Bleeder circuit for Triac holding current.

To use MAP901X as triac-dimming version MODE pin has to opened but to avoid noise we are recommended connected by capacitor. Typical application circuit shown as Fig8.

Triac-dimming mode of MAP9010

MAP9010's Triac-dimming version has to connection of capacitor to Mode pin and GND pin. And this Triac-dimming board need to some extra circuit as holding current circuit and VCC supply circuit. Refer to Figure 14.

CDIM function

Rline is detected information of input voltage. Because the typical application use holding circuit, VIN reached zero and Rline voltage also reached zero according to divide resistor. Normally triac-dimming function of AC-direct solution has a shimmer at low-angle because conduction angle of triac dimmer is difference pulse by pulse as below picture. (Figure 11)

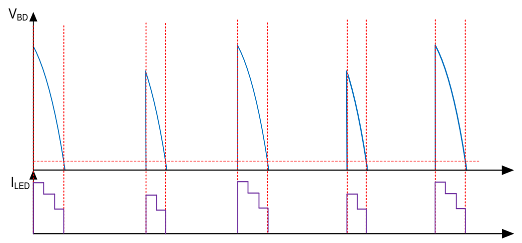


Figure11. Shimmering of AC-direct solution

This current waveform has a shimmer because LED current area is different

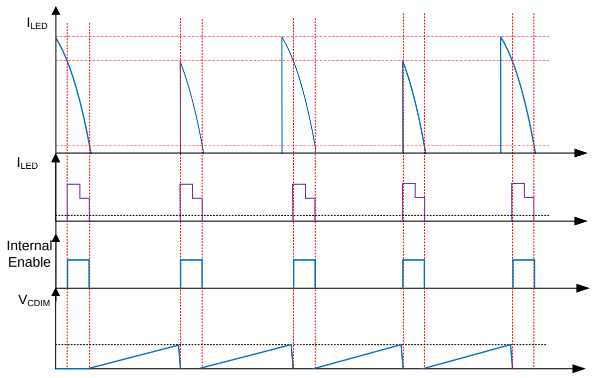


Figure11. CDIM operation of MAP9010

CDIM pin is connecting external capacitor and this pin starts charging when CS pin reached about 0.4V. This point is same VIN voltage falling to zero. CDIM internal sourcing current is typical 8.5uA.

This pin is operating as AC off time detector. Even if AC voltage is difference dimmer positive and negative, MAP9010 can come out the same LED output current

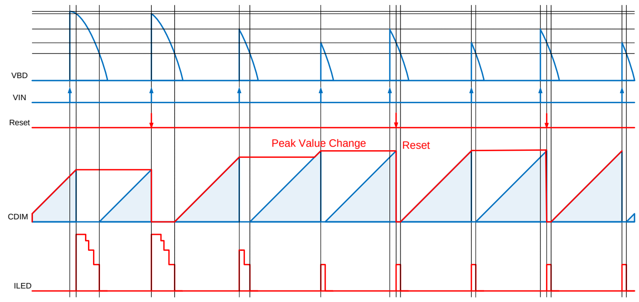


Figure12. Angle change (Max angle → Min angle)

The CDIM Peak value is reset every two cycles in order to prevent a malfunction when the change.

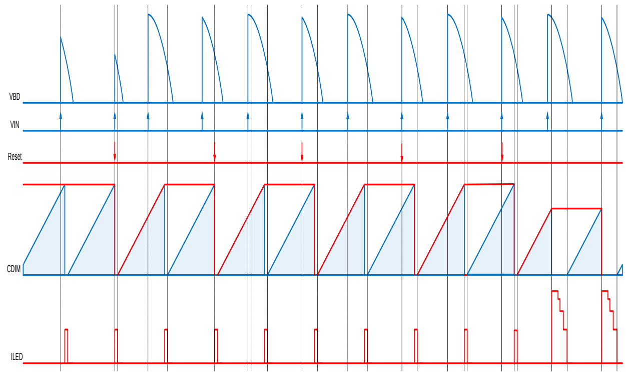


Figure13. Angle change (Min angle → Max angle)

Minimum Angle off Function.

Figure14 show minimum angle off operation. MAP9010's CDIM discharging required meet below condition. First Vin voltage has to reached target voltage call for Rline sensing (V_{RSE}) voltage is detected by Rline voltage.

Second CDIM peak value has to reached previous CDIM peak value; this is off-timer detection to reduce shimmer of AC-direct solution.

So if VIN is not reached target Rline sensing voltage, CDIM remains charging. And CDIM voltage is reached CDIM reset voltage, LED current is off and IC became disabling.

This moment, Rline sensing voltage (V_{RSE}) is change to having a some hysteresis about 0.9V.

So If minimum angle is remain, LED current is never turn-on. But angle is re-increasing and Vin touch Rline sensing voltage + 0.9V (hysteresis) LED current can be flow through internal IC FET. This moment Rline sensing voltage is itself again.

This operation is very important operating as Traic-dimming mode. So CDIM charging time is very important and that's variable is CDIM charging current, CDIM reset voltage, CDIM capacitance.

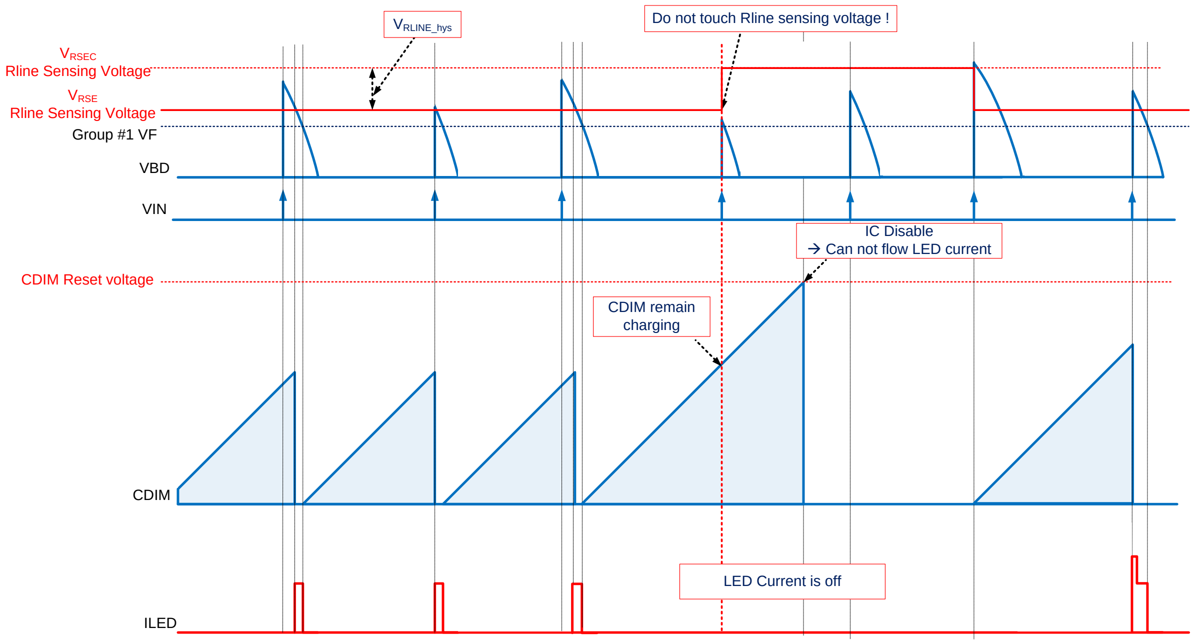


Figure14. Minimum angle off operation

Traic-dimming's gate trigger voltage can be varied according to AC line voltage. This variation depends on conduction angle change and MAP9010 can be detected AC line angle change. To carry angle detection out perfectly without another abnormal operation, bleeder circuit has to apply in the circuit.

Bleeder Circuit Operation

MAP9004 applied bleeder circuit can constant current control by sensing resistor. MAP9004's current control is negative voltage of sensing resistor across voltage. If sensing resistor voltage reached zero; this case is VIN is zero bias or additional current flow from MAP9010 side; MAP9004 (holding circuit) can't flow holding current.

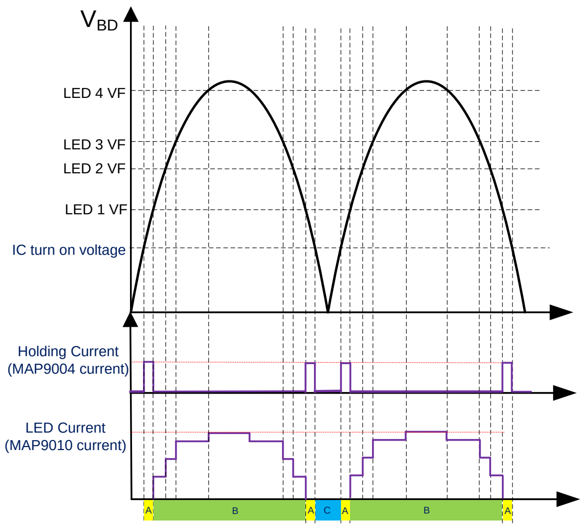


Figure15. Bleeder circuit operation

CDIM must not touch CDIM reset voltage before minimum angle, and must touch CDIM reset voltage at target minimum angle. So CDIM capacitor must be not change temperature and other SPL.. We are recommended that applied NP0 type MLCC as below. (SPL variation has to under ±1%)

Application for triac dimming operation.

To prevent CDIM abnormal operation the application circuit has to change. Only using CDIM current, it is insufficient. So MAP9010 provide another bias current using RDIM pin.

Once MAP9010's mode is change as triac dimming (MODE pin to GND connected capacitor) internal VDD voltage supplied to RDIM pin. VRDIM (OUT) is internal bias of RDIM pin as operation of traic dimming mode.

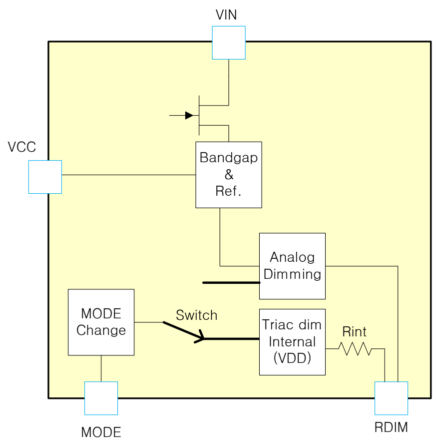


Figure16. Internal block

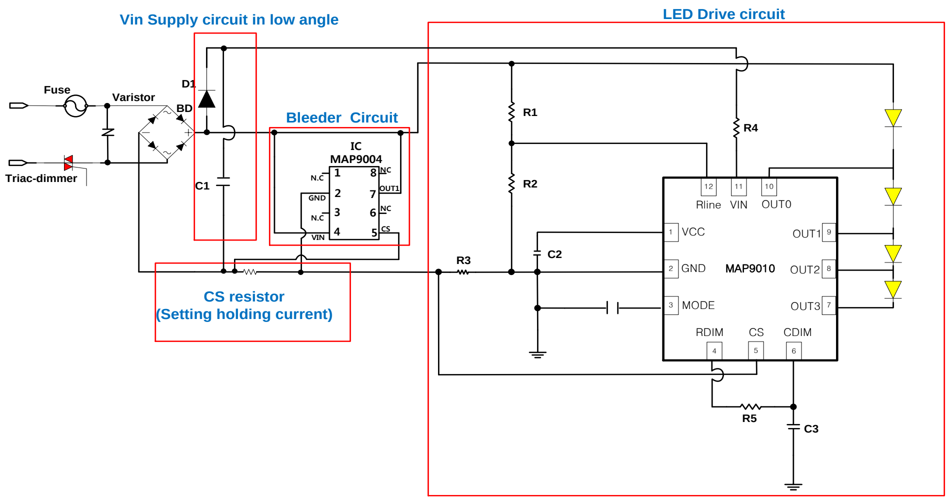


Figure17. Typical Application Circuit for MAP9010 Traic-diming version

It was mentioned above CDIM must not touch CDIM reset voltage before minimum angle, and must touch CDIM reset voltage at target minimum angle. So IC's internal current and voltage spec very important like Rint & internal VDD ($V_{RDIM(OUT)}$) & CDIM reset voltage & CDIM current. But most important thing is external capacitance and resistance because the main factor that determined CDIM charging time is that.

Select CDIM capacitor & RDIM resistor.

In Traic-dimming mode, The CDIM capacitor and RDIM resistance is fixed.(R5, C3 in Fig15)

This component is very important for Triac-dimming operation. So this capacitor and resistor's tolerance and temperature coefficient also important.

So we are recommended as below.

1. Capacitor (C3, Fig15)

120V Application	Type	Tolerance	Rated Voltage	C Value
Input 120V/50Hz	C0G (NP0)	± 5 %	Over 10V	100nF
Input 120V/60Hz				

2. Resistor (R5, Fig15)

120V Application	TCR	Tolerance	Rated Voltage	R Value
Input 120V/50Hz	Below 100ppm	± 1%	Over 10V	330KΩ
Input 120V/60Hz				270KΩ

As shown in Figure 17, region 'A' represents holding current. This current control by MAP9004's sensing resistor and that is cut off when MAP9010's current flow through MAP9004's sensing resistor.

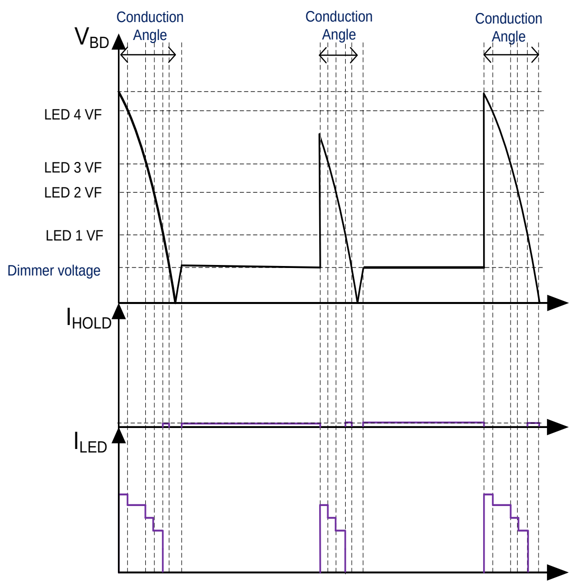


Figure18. VIN waveform in low hold current.

If hold current is small or there is no holding current, the VIN waveform is not reached zero. Then MAP9101 cannot angle detect. The holding current setting by MAP9004's sensing resistor.

Set hold current.

MAP9004 can flow current when VIN voltage reached MAP9004's minimum start-up voltage. (Min 25V)

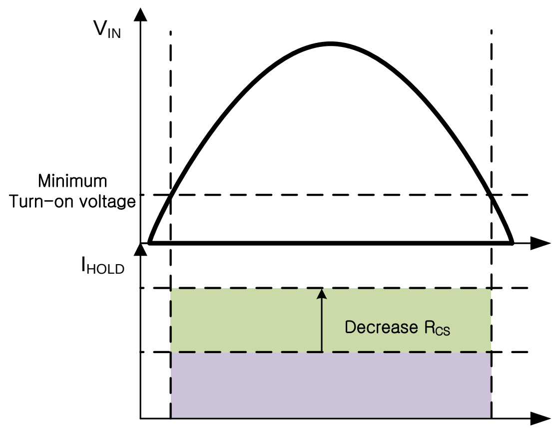


Figure19. MAP9004 current control

And MAP9004 performed as constant current controller. And this current can change by sensing resistor. (R_{CS}) Normally the holding current range is 20mA ~ 50mA. And MAP9004's current setting formula as below,

$$I_{HOLD} = 185mA \times \frac{6.8ohm}{R_{CS}}$$

So if RCS is 33ohm, the holding current is

$$I_{HOLD} = 185mA \times \frac{6.8ohm}{33ohm} = 38.1mA$$

Therefore if RCS is 33ohm fixed, the holding current is about 38mA.

VCC supply circuit.

HV pin of MAP9010 is supplied VCC power. So if VIN became very small: it means traic-dimmer's angle is minimum; VCC is risk for entered under voltage lock out.

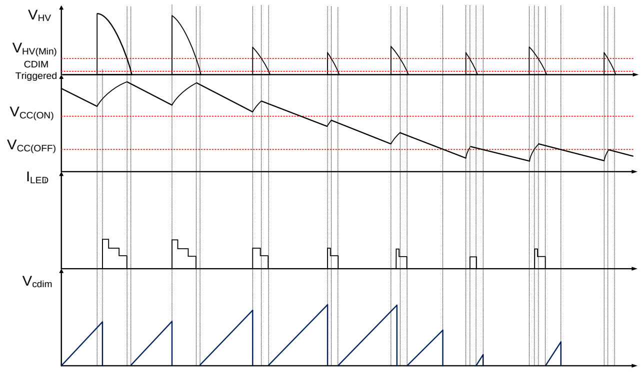


Figure20. UVLO operation at minimum angle.

To avoid this un-control region, below application has to apply.

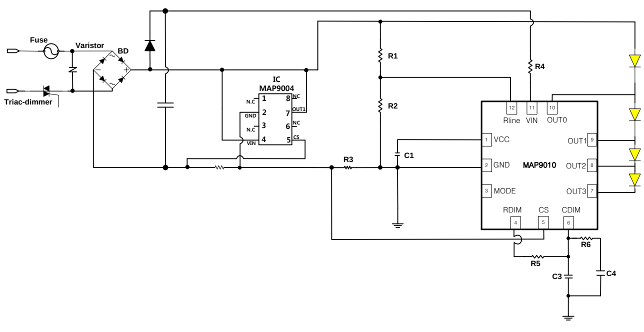
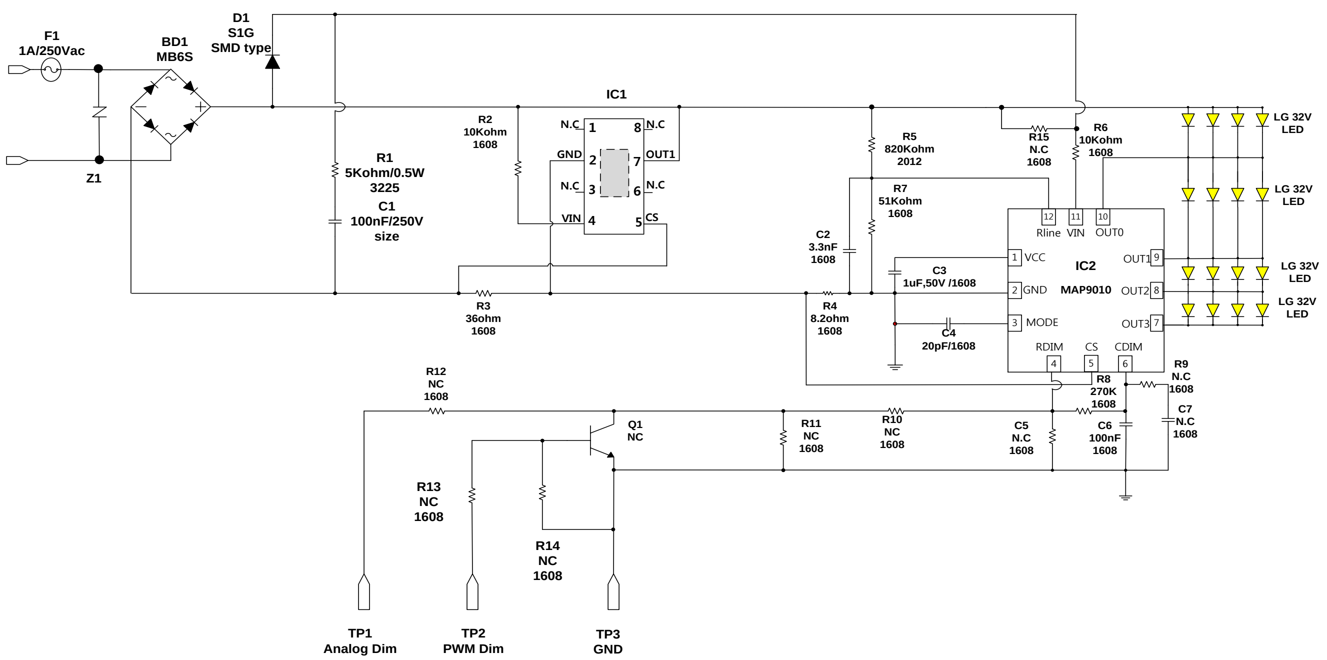


Figure21. VCC stable circuit

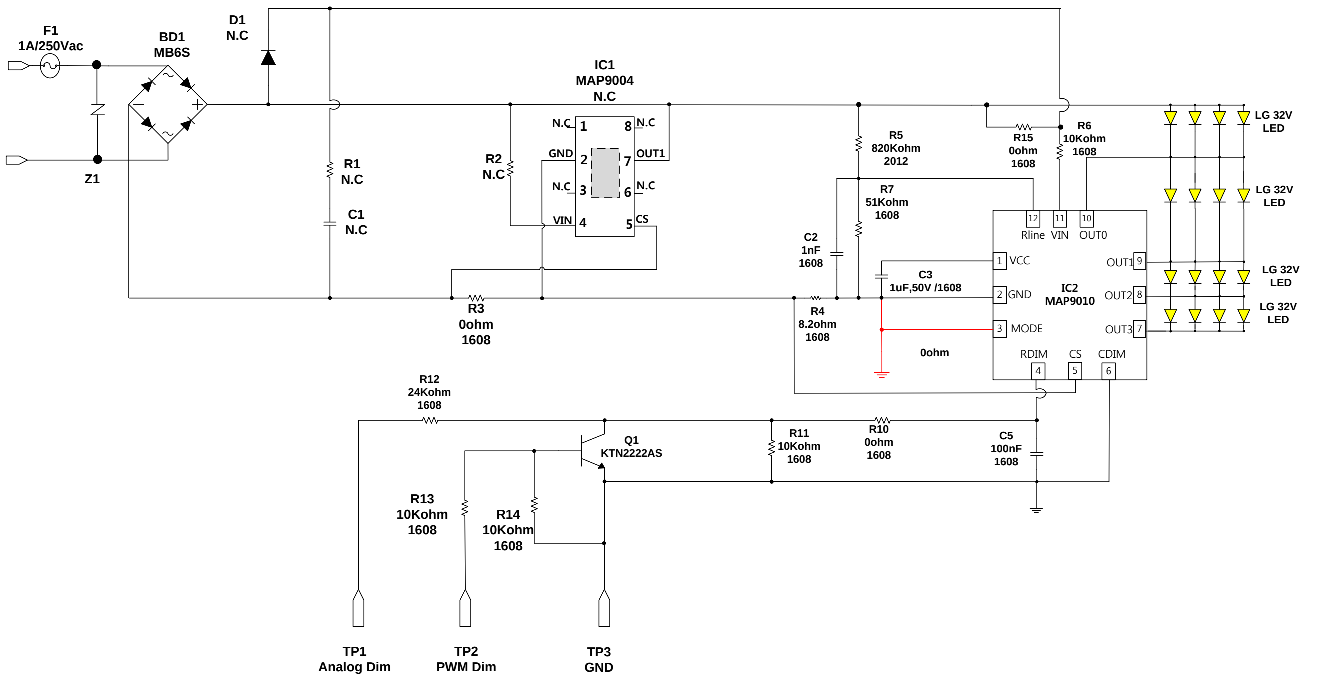
When applying this circuit, HV pin voltage is always on HV (min) voltage. So VCC is always DC voltage and system became stable.

Demo-board Circuit.

1. Triac Dimming Circuit



2. ADIM Dimming Circuit



Dimmer Compatibility list.

Dimmer NUM	Maker	Part num	Min	Max	Flicker	Shimmer
#1	COOPER	MLV-600VA	0.47W	17.3W	NO	Bad
#2	DAIKO	DP-36766F	0.5W	10.75W	NO	Normal
#3	JAPAN(100V)	AEE690178	0.36	10.86	Yes	Bad
#4	LUTRON	LGCL-153PL	0.5W	16.69W	NO	Normal
#5	LUTRON	1E14I1	1.16W	18.3W	NO	Normal
#6	DIVA	DV-600p	0.925W	16.97W	NO	Good
#7	LUTRON	LGCL-153P	0.5W	16.81W	NO	Bad
#8	LUTRON	1C3305	1.07W	17.23W	NO	**Good**
#9	LUTRON	1C5406	1.079W	17.22W	NO	Good
#10	Legrand	HCL453P	2.87W	17.014W	NO	Good

Demo-board Part list (T.B.D)