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# Application Note AN-3003

## Applications of Random Phase Crossing Triac Drivers

### Construction

The MOC30XX family of random phase (non-zero crossing) triac drivers consist of an aluminum gallium arsenide infrared LED, optically coupled to a silicon detector chip. These two chips are assembled in a 6 pin DIP package, providing 7.5KV<sub>AC(PEAK)</sub> of insulation between the LED and the output detector. These output detector chips are designed to drive triacs controlling loads on 115 and 220V AC power lines. The detector chip is a complex device which functions in the same manner as a small triac, generating the signals necessary to drive the gate of a larger triac such as Fairchild's FKPF12N80. The MOC30XX triacs are capable of controlling larger power triacs with a minimum number of additional components.

Table 1 lists the members of the MOC30XX random phase triac driver family. The family is divided by blocking voltage,  $V_{DM}$ , and input LED trigger sensitivity,  $I_{FT}$ . MOC3010/1/2 are rated at 250V, the MOC3020/1/2/3 are 400VAC, and the MOC3051/2 have a  $V_{DM}$  of 600V.

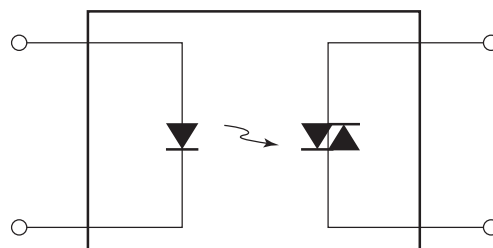
### Basic Electrical Description

The AlGaAs LED has a nominal 1.3 V forward drop at 10 mA and a reverse breakdown voltage greater than 3 V. The maximum current to be passed through the LED is 60 mA.

The detector has a minimum blocking voltage of 250 Vdc in either direction in the off state. In the on state, the detector will pass 100 mA in either direction with less than 3 V drop

across the device. Once triggered into the on (conducting) state, the detector will remain there, even if no current flows through the LED, until the terminal current drops below the holding current (typically 100  $\mu$ A) at which time the detector reverts to the off (non-conducting) state. The detector may be triggered into the on state by exceeding the forward blocking voltage, by voltage ramps across the detector at rates exceeding the static dv/dt rating, or by photons from the LED. The LED is guaranteed by the specifications to trigger the detector into the on state when the current passing through the LED is equal to, or greater than the  $I_{FT(max)}$  specification. For example the MOC3011M requires at least 10mA of LED current to guarantee turn-on. A similar device, the MOC3012M, has exactly the same characteristics except it requires only 5 mA to trigger.

Since these devices look essentially like a small optically triggered triac, we have chosen to represent it as shown in Figure 1.



**Figure 1. Schematic Representation of an Optically Coupled Random Phase Triac Driver**

		Random Pase Triac Optocouplers						
		Part Number	$I_{FT}$ (ma) max	$V_{TM}$ (V) max	$V_{DM}$ (V) min	$I_H$ ( $\mu$ A)	$I_{DRM}$ (nA) max	$V_{ISO}$ AC[PEAK]
<p>ANODE 1</p> <p>CATHODE 2</p> <p>NC 3</p> <p>6 MAIN TERM</p> <p>5 *</p> <p>4 MAIN TERM</p> <p>*Do not connect</p>	MOC3010M	15	3	250	100	100	7.5kV	
	MOC3011M	10	3	250	100	100	7.5kV	
	MOC3012M	5	3	250	100	100	7.5kV	
	MOC3020M	30	3	400	100	100	7.5kV	
	MOC3021M	15	3	400	100	100	7.5kV	
	MOC3022M	10	3	400	100	100	7.5kV	
	MOC3023M	5	3	400	100	100	7.5kV	
	MOC3051M	15	2.5	600	280	100	7.5kV	
	MOC3052M	10	2.5	600	280	100	7.5kV	

**Table 1.**

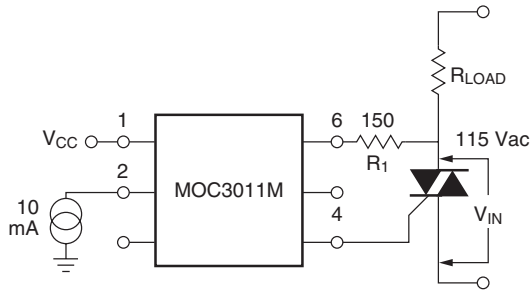
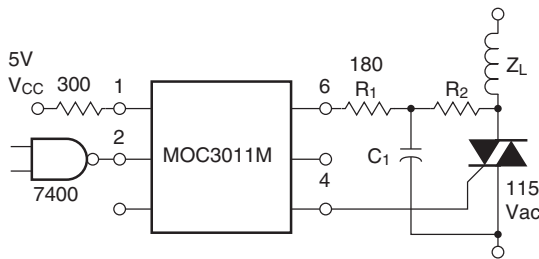


Figure 2. Simple Triac Gating Circuit



NOTE: Circuit supplies 25mA drive to gate of triac at  $V_{in} = 25V$  and  $T_A < 70^\circ C$

TRIAC		
$I_{GT}$	$R_2$	C
15 mA	2400	0.1
30 mA	1200	0.2
50 mA	800	0.3

Figure 3. Logic to Inductive Load Interface

## Using the MOC3011M as a Triac Driver

### Triac Driving Requirements

Figure 2 shows a simple triac driving circuit using the MOC3011M. The maximum surge current rating of the MOC3011M sets the minimum value of  $R_1$  through the equation:

$$R_1 (\text{min}) = V_{in}(\text{pk})/1.2A$$

If we are operating on the 115 Vac nominal line voltage,  $V_{in}(\text{pk}) = 180 V$ , then

$$R_1 (\text{min}) = V_{in}(\text{pk})/1.2A = 150 \text{ ohms.}$$

In practice, this would be a 150 or 180 ohm resistor. If the triac has  $I_{GT} = 100 \text{ mA}$  and  $V_{GT} = 2 V$ , then the voltage  $V_{in}$  necessary to trigger the triac will be given by,

$$V_{inT} = R_1 \cdot I_{GT} + V_{GT} + V_{TM} = 20 V.$$

### Resistive Loads

When driving resistive loads, the circuit of Figure 2 may be used. Incandescent lamps and resistive heating elements are the two main classes of resistive loads for which 115 Vac is utilized. The main restriction is that the triac must be properly chosen to sustain the proper inrush loads. Incandescent lamps can sometimes draw a peak current known as “flash-over” which can be extremely high, and the triac should be protected by a fuse or rated high enough to sustain this current.

### Line Transients-Static dv/dt

Occasionally transient voltage disturbances on the ac line will exceed the static dv/dt rating of the MOC3011M. In this case, it is possible the MOC3011M and the associated triac will be triggered on. This is usually not a problem, except in unusually noisy environments, because the MOC3011M and its triac will commute off at the next zero crossing of the line voltage, and most loads are not noticeably affected by an occasional single half-cycle of applied power. See Figure 4 for typical dv/dt versus temperature curves.

### Inductive Loads-Commutating dv/dt

Inductive loads (motors, solenoids, magnets, etc.) present a problem both for triacs and for the MOC3011M because the voltage and current are not in phase with each other. Since the triac turns off at zero current, it may be trying to turn off when the applied current is zero but the applied voltage is high. This appears to the triac like a sudden rise in applied voltage, which turns on the triac if the rate of rise exceeds the commutating dv/dt of the triac or the static dv/dt of the MOC3011M.

### Snubber Networks

The solution to this problem is provided by the use of “snubber” networks to reduce the rate of voltage rise seen by the device. In some cases, this may require two snubbers—one for the triac and one for the MOC3011M. The triac snubber is dependent upon the triac and load used and will not be discussed here. In many applications the snubber used for the MOC3011M will also adequately protect the triac.

In order to design a snubber properly, one should really know the power factor of the reactive load, which is defined as the cosine of the phase shift caused by the load. Unfortunately, this is not always known, and this makes snubbing network design somewhat empirical. However, a method of designing a snubber network may be defined, based upon a typical power factor. This can be used as a “first cut” and later modified based upon experiment.

Assuming an inductive load with a power factor of  $PF = 0.1$  is to be driven. The triac might be trying to turn off when the applied voltage is given by

$$V_{to} = V_{pk} \sin \theta = V_{pk} = 180 V$$

First, one must choose  $R_1$  (Figure 3) to limit the peak capacitor discharge current through the MOC3011M. This resistor is given by

$$R_1 = V_{pk}/I_{max} = 180/1.2 \text{ A} = 150\Omega$$

A standard value, 180 ohm resistor can be used in practice for  $R_1$ .

It is necessary to set the time constant for  $\tau = R_2C$ . Assuming that the triac turns off very quickly, we have a peak rate of rise at the MOC3011M given by

$$dv/dt = V_{to}/\tau = V_{to}/R_2C$$

Setting this equal to the worst case  $dv/dt$  (static) for the MOC3011M which we can obtain from Figure 4 and solving for  $R_2C$ :

$$dv/dt(T_J = 70^\circ\text{C}) = 0.8 \text{ V}/\mu\text{s} = 8 \times 10^5 \text{ V/s}$$

$$R_2C = V_{to}/(dv/dt) = 180/(8 \times 10^5) = 225 \times 10^{-6}$$

The largest value of  $R_2$  available is found, taking into consideration the triac gate requirements. Using Fairchild's power triac, FKPF12N80,  $I_{GT} = 30 \text{ mA}$ . If the triac is to be triggered when  $V_{in} \leq 40\text{V}$ :

$$(R_1 + R_2) = V_{in}/I_{GT} = 40/0.030 \approx 1.33 \text{ k}$$

If we let  $R_2 = 1200 \Omega$  and  $C = 0.1 \mu\text{F}$ , the snubbing requirements are met. Triacs having less sensitive gates will require that  $R_2$  be lower and  $C$  be correspondingly higher as shown in Figure 3.

## Input Circuitry

### Resistor Input

When the input conditions are well controlled, as for example when driving the MOC3011M from a logic gate, only a single resistor is necessary to interface the gate to the input LED of the MOC3011M. The resistor should be chosen to set the current into the LED to be a minimum of 10 mA but no more than 50 mA. 15 mA is a suitable value, which allows for considerable degradation of the LED over time, and assures a long operating life for the coupler. Currents higher than 15 mA do not improve performance and may hasten the aging process inherent in LED's. Assuming the forward drop to be 1.5 V at 15 mA allows a simple formula to calculate the input resistor.

$$R_I = (V_{CC} - 1.5)/0.015$$

Examples of resistive input circuits are seen in Figures 1 and 5.

### Increasing Input Sensitivity

In some cases, the logic gate may not be able to source or sink 15 mA directly. CMOS, for example, is specified to have only 0.5 mA output, which must then be increased to drive the MOC3011M. There are numerous ways to increase this current to a level compatible with the MOC3011M input requirements; an efficient way is to use the Fairchild TinyLogic™, NC7SZ04 shown in Figure 5.

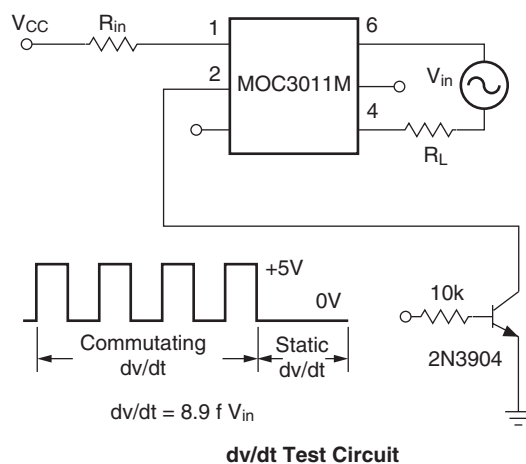
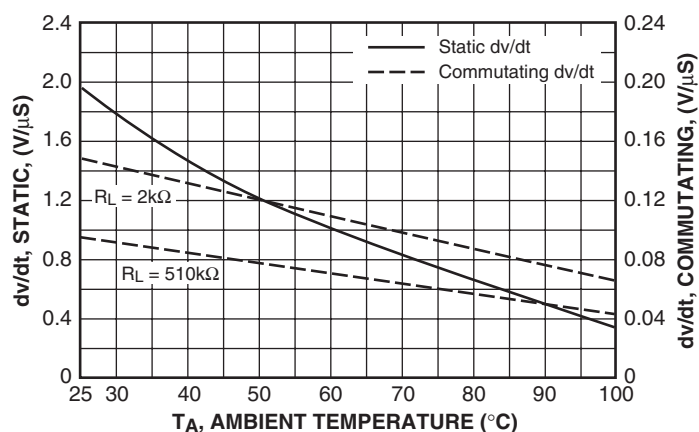


Figure 4.  $dv/dt$  versus Temperature

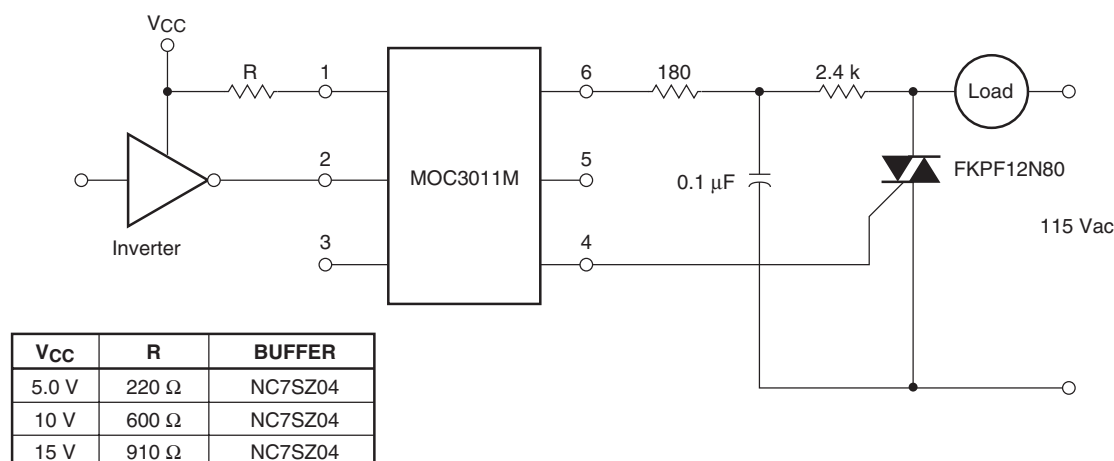


Figure 5. MOS to AC Load Interface

### Input Protection Circuits

In some applications, such as solid state relays, in which the input voltage varies widely the designer may want to limit the current applied to the LED of the MOC3011M. The circuit shown in Figure 6 allows a non-critical range of input voltages to properly drive the MOC3011M and at the same time protects the input LED from inadvertent application of reverse polarity.

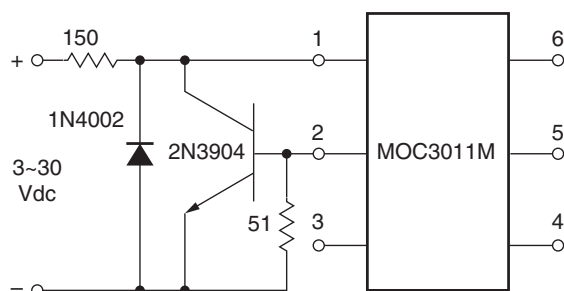


Figure 6. MOC3011M Input Protection Circuit

### LED Lifetime

All light emitting diodes slowly decrease in brightness during their useful life, an effect accelerated by high temperature and high LED currents. To allow a safety margin and ensure long service life, the MOC3011M is actually tested to trigger at a value lower than the specified 10 mA input

threshold current. The designer can therefore design the input circuitry to supply 10 mA to the LED and still be sure of satisfactory operation over a long operating lifetime. On the other hand, care should be taken to ensure that the maximum LED input current (50 mA) is not exceeded or the lifetime of the MOC3011M may be shortened.

## Applications Examples

### Using the MOC3011M on 240 Vac Lines

The rated voltage of a MOC3011M is not sufficiently high for it to be used directly on 240 Vac line; however, the designer may attach two of them in series. When used this way, two resistors are required to equalize the voltage dropped across them as shown in Figure 7.

### Remote Control of ac Voltage

Local building codes frequently require all 115 Vac light switch wiring to be enclosed in conduit. By using a MOC3011M, a triac, and a low voltage source, it is possible to control a large lighting load from a long distance through low voltage signal wiring which is completely isolated from the ac line. Such wiring usually is not required to be put in conduit, so the cost savings in installing a lighting system in commercial or residential buildings can be considerable. An example is shown in Figure 8. Naturally, the load could also be a motor, fan, pool pump, etc.

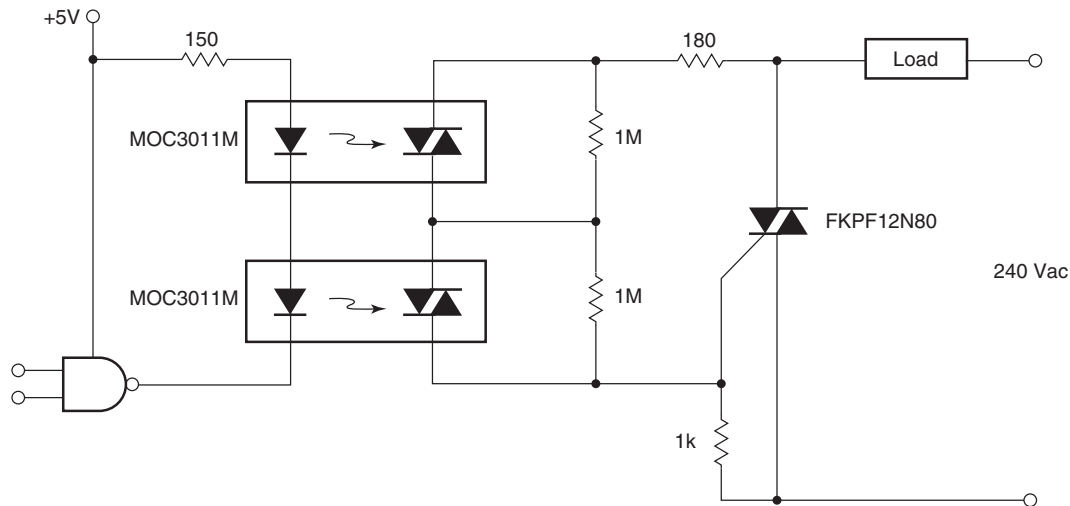


Figure 7. 2 MOC3011M Triac Drivers in Series to Drive 240 V Triac

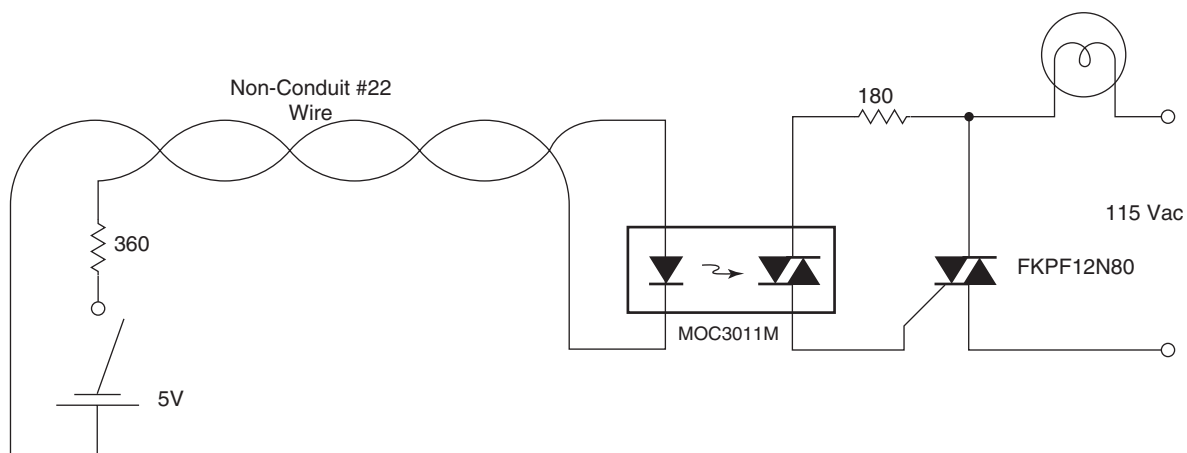


Figure 8. Remote Control of AC Loads through Low Voltage Non-Conduit Cable

### Solid State Relay

Figure 9 shows a complete general purpose, solid state relay snubbed for inductive loads with input protection. When the designer has more control of the input and output conditions, he can eliminate those components which are needed for his particular application to make the circuit more cost effective.

### Interfacing Microprocessors to 115 Vac Peripherals

The output of a typical microcomputer input-output (I/O) port is a TTL-compatible terminal capable of driving one or two TTL loads. This is not quite enough to drive the MOC3011M, nor can it be connected directly to an SCR or

triac, because computer common is not normally referenced to one side of the ac supply. The Fairchild TinyLogic™ NC7SZ04 UHS inverter can provide the LED current drive required by the MOC3011M family. If the second input of a 2 input gate is tied to a simple timing circuit, it will also provide energization of the triac only at the zero crossing of the ac line voltage as shown in Figure 10. This technique extends the life of incandescent lamps and reduces EMI generated by load switching. Of course, zero crossing can be generated within the micro-computer itself, but this requires considerable software overhead and usually just as much hardware to generate the zero-crossing timing signals.

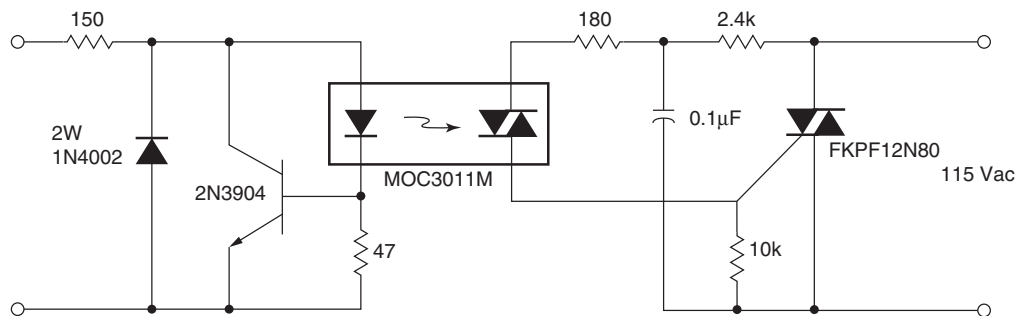


Figure 9. Solid-State Relay

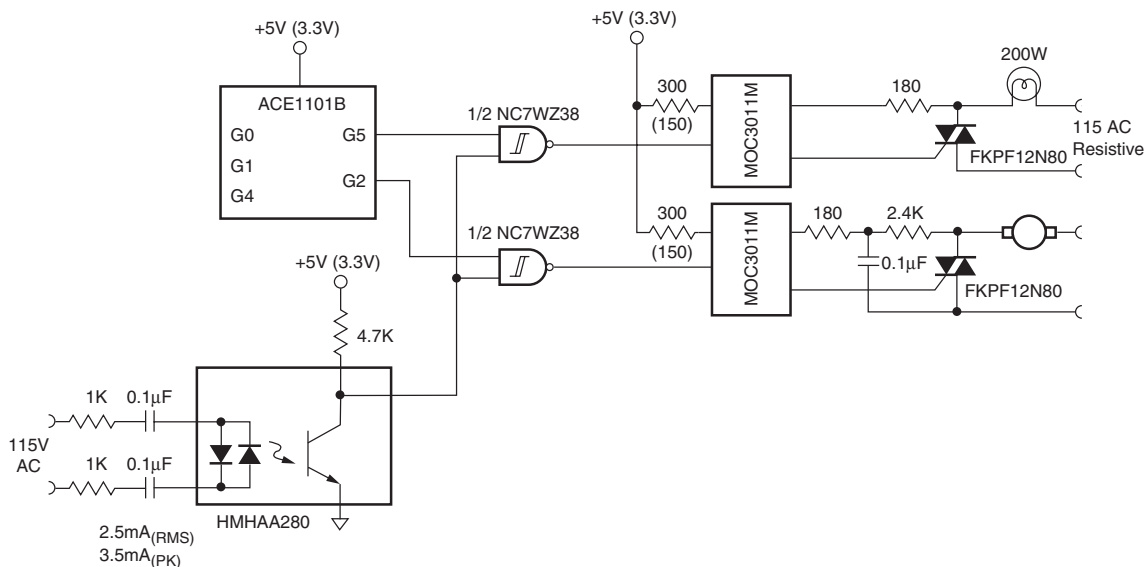


Figure 10. Interfacing an Arithmetic Controller Engine to 115 Vac Loads

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