

Introduction

Halogen lamps are preferable to incandescents in many applications due to their increased brightness and longevity. Halogen bulbs are used in many varied applications, such as:

- automotive headlamps
- police vehicle-top flashers
- ambulance, tow truck, fire engine-top flashers
- machine vision
- fiber optic illumination
- large scale lighting displays
- medical and analytical equipment
- school bus flashers

Halogen Lamps vs. Incandescent

A typical incandescent lamp is a glass bulb filled with an inert gas (such as krypton or argon) with a tungsten filament in the center. The filament glows as a potential difference is applied across the terminals of the bulb, giving off light and heat. However, the tungsten molecules are evaporating from the filament to cause this glow; the convection currents of the fill gas carry these molecules to the cooler inner surface of the bulb wall where they are deposited. This decreases bulb output and life in two ways: first, the effective filament diameter is decreased, which increases the resistance of the bulb, and second, the glass is "blackened" by these deposits. This mechanism limits the wattage that a conventional lamp can be used at if a satisfactory lifetime is to be achieved.

A halogen lamp operates in the same manner, except that a small amount of halogen gas has been added to the fill gas; this halogen is normally bromine. When the bulb wall temperature reaches roughly 250°C, the "halogen regenerative cycle" begins to take place. The evaporated tungsten molecules now combine with the free halogens to form a tungsten halide compound with a condensation temperature below the wall temperature. Hence, the tungsten does not settle on the glass wall, but returns to the filament where it is redeposited. This process accounts for the almost infinite lifetime of halogens as compared to incandescents. As this cycle begins at a wall temperature of 250° C, the filament must not only generate light but must also maintain this high temperature. Gas pressure is also higher in a halogen bulb than in an incandescent bulb, which retards the tungsten evaporation and allows operation at higher temperatures and greater efficiencies. This is why they are brighter than normal incandescent bulbs.

Basic Considerations

Although halogens operate similarly to incandescents, they do have some key differences that must be taken into consideration while designing/prototyping with them. Most

obviously, it is important not to touch or look directly at them while testing as they do operate at greatly increased temperatures and brightness levels. Tinted safety glasses or sunglasses should be worn while working with halogens. Also, as the condition of the glass wall is crucial to the halogen regenerative cycle, it is important not to leave finger marks or imprints on the glass surface. At best, the imprint will be permanently etched into the glass. At worst, the bulb will explode due to the change in pressure (halogens operate at a high internal gas pressure). To remedy this, any finger marks can be cleaned off the bulb prior to use with acetone or propanol.

As the filament must generate the heat necessary to maintain the wall temperature of 250 ° C, it is important not to operate the lamp at any more than 10% (continuously) below its rated design voltage. As halogen lamps are usually designed to their maximum limits, it is also not recommended that they be operated at a continuous voltage higher than the rated design voltage. Operation above rated voltage is considered the single most damaging factor in terms of lamp lifetime. Unfortunately, since incandescents do not have this restriction, this is commonly overlooked.

Special sockets/holders are also required due to the high temperatures generated. For bulbs rated at 35 Watts or below, heat resistant phenolic (hard plastic) holders are adequate. Bulbs rated at 50 Watts or above require the use of special ceramic holders; two excellent sources of supply for such holders are Gilway Technical Lamp, and GTE Sylvania.

A Simple Power MOSFET Drive Circuit

A major consideration when driving halogen lamps is the inrush current generated when starting up a cold filament. This inrush can range from 20 A to 100 A and lasts from 10 to 100 ms depending on the construction of the lamp. As power MOSFETs have large peak currents and wider SOAs (safe operating areas) than do bipolar junction transistors, they are a good choice for driving halogen lamps. N-channel MOSFETs are more cost effective and have lower on resistances than P-channel MOSFETs. However, N-channel MOSFETs require a significant gate enhancement above the positive rail when driving a grounded load. This necessitates the use of a charge pump.

A MIC5010 family MOSFET predriver and an N-channel power MOSFET make an excellent drive circuit for a halogen lamp. The MIC5010 family of predrivers have an on-board charge pump, which saves space and design time. The MIC5013 also offers an over current sense feature to detect a

short circuit and turn off the power FET in time (10 μ s typical shutdown time) to prevent damage. This overcurrent shutdown can be delayed such that the initial inrush current doesn't cause a false triggering of this protection feature. This can easily be accomplished by adding an RC network to the threshold pin of the MIC5013 such that the initial trip point is very high, but decays with time to a reasonable value (figure 1).

The design equations as shown are used in this circuit to set a final current trip point of roughly twice the current needed by the lamp. R_{TH2} is used to increase the current limit at turn-on to roughly 10X the steady-state value. The choice of C_{TH} governs the time constant or decay of the high initial trip point, and will need to be varied depending on the time constant of the inrush current of the particular lamp used. This design has a 20 ms time constant.

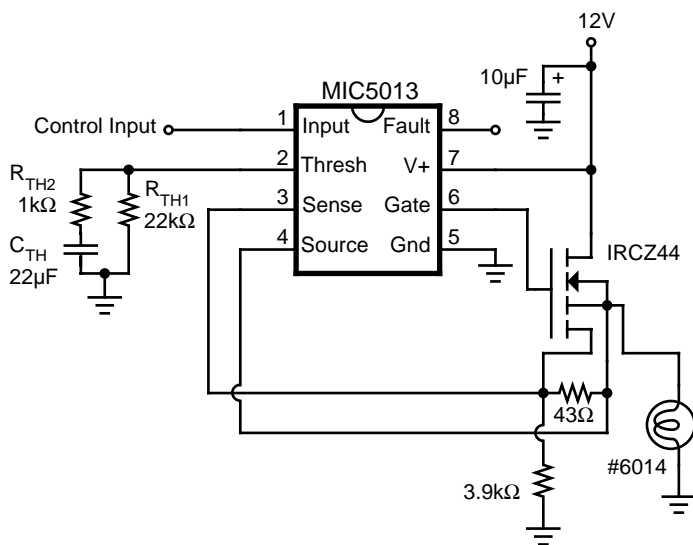


Figure 1. Time-Variable Trip Threshold

If the lamp being driven by this circuit is pulse-width modulated, extra care must be taken in choosing a PWM frequency and capacitor value. When the device is switched off, the threshold pin appears as an open circuit and C_{TH} is discharged through the two resistors. This is a slower process than the turn-on time constant; any residual charge in the capacitor will act to reduce the current limit. If the device is switched at certain frequencies, (dependent on capacitor value) the capacitor will have time to charge during every cycle, but not to discharge properly. This can lead to erroneous over current shutdown at normal operating currents.

A 75X/Minute Halogen Flasher Circuit

Illustrated in Figure 2 is a 75X/minute, 50% duty cycle halogen flasher circuit, prototyped using six MIC5011s and six 100 Watt halogen bulbs. Over current sensing was not used for this prototype, but could easily be added to each lamp by using

MIC5013s per figure 1. The drains of the power FETs, the timing circuit and the MIC5011s were all driven from one power supply.

Potential applications for this design are tops of emergency vehicles such as ambulances and police cars, school bus flashers, turn signals, beacons, and large scale lighting displays.

Government specification KKK – A – 1822C, which governs flashers for emergency vehicles, dictates that a 50% duty cycle with a variation of no more than 3% be used. The timing circuit shown in figure 2 achieves this by first creating a clean 50% duty cycle signal from a 7555 (CMOS 555) at twice the needed flashing frequency, or 150 X/minute. This is accomplished by using equal resistors and diodes, as shown. This

$$R_s = \frac{SR (V_{TRIP} + 100mV)}{R I_L - (V_{TRIP} + 100mV)}$$

$$R1 = \frac{V + SRR_s}{100mV (SR + R_s)}$$

$$R_{TH} = \frac{220}{V_{TRIP}} - 1000$$

For this example:

$$I_L = 30A \text{ (trip current)}$$

$$V_{TRIP} = 100mV$$

clean, but not quite in-spec, oscillator is then fed into a CD4013 D flip-flop configured as a simple "divide-by-two" circuit. This ensures that the duty cycle is 50% with very little error. It is crucial to bypass both chips with a 0.01 μ F ceramic disc capacitor from V_{CC} to ground, as system noise will greatly affect the accuracy of this oscillator.

This design has one set of three lamps flashing 180 degrees out of phase with the other group of three, emulating the red and blue halves of a police car-top. This is accomplished easily by using the \bar{Q} output of the flip-flop for the one set and the Q output for the other. The set and reset functions of the flip-flop, tied to ground in this prototype, could be used to provide external control of the flasher (ie, to turn it on constantly or shut it down).

This specification also stipulates that the maximum voltage drop across the entire flasher be not more than 0.5V. The best way to achieve this is by the use of low $R_{DS(on)}$ power FETs.

This is crucial for other reasons as well; the current requirements are very stringent for this system. If the switch loss is not kept to a minimum, the lamps may not receive adequate voltage for turn on. Also, the $I^2 R$ loss associated with the switch creates a great deal of heating that can cause the early demise of the power FET. Chosen for this design was the IRFZ40, which has an $R_{DS(on)}$ of 28 m Ω , a peak drain current rating of 160A, and a continuous drain current rating of 35A. A high peak as well as continuous current rating is crucial as the inrush currents for each lamp may be as high as 100A, and the continuous current will be 5 to 10A. (This of course, varies widely from lamp to lamp). The drawback that this power FET has is that it is only rated to 50V. If a system with high voltage spikes is used, then some form of protection such as power zeners or Transzorbs will be necessary (a FET with a higher peak V_{DS} can be used if a higher $R_{DS(on)}$ can be tolerated).

Prototyping this design requires that the FETs be adequately heat sunk to prevent damage. A large 1/8" thick aluminum heat sink was employed, with the power FETs spaced roughly 2" apart. The final package used should also allow for adequate heat sinking, to prolong the operating life. The lamps should NOT be heat sunk, as they must reach high temperatures to initiate the halogen cycle.

As the lamps are driven in parallel, the currents are additive. Very high currents are generated during the inrush stage; this requires that #10 (or similar) copper wire be used for the V_{CC} and ground connections to the power supply. If the power supply used in prototyping doesn't have the current capability to start up the lamps, a car battery may be used.

Finally, the lamps and MIC5011s must be operated from a common ground. If connected to ground via long wires or to separate grounds, a "ground loop" or situation where one ground is actually at some potential above the other ground may result. Such a resistive ground may result in a current flow that prevents proper lamp turn off between flashes. Use of either a single point ground or a chassis ground to form a ground plane will prevent this. If this is impossible, optoisolators may be effectively used to "open" such ground loops, eliminating this problem (see the [Hewlett Packard Optoelectronics Applications Handbook](#) for more details).

A 120X/Minute Flasher Design

As an alternative to the above design, a higher frequency design with longer on-time is shown in figure 3. The design methodology is to prolong lamp life by maximizing on time. This design does not meet the government specification referenced earlier, but is suggested for applications where long service life is essential.

Possible applications include hazard lighting, beacons, large scale lighting displays, emergency vehicle tops not covered by the referenced specification, and large scale lighted store front signs.

Timing is controlled via a simple 7555 (CMOS 555) circuit, set to flash the lamps 120X/minute. The duty cycle is set to insure an on time of 65% and an off time of 35%, which gives a visible flashing while allowing the lamps to remain on long enough to achieve the necessary wall temperatures. Slower flashing frequencies (or shorter on-times at this frequency) will reduce the lifetime of the lamps by allowing them to cool down between blinks. This reduced filament life is due to the lamp completely reheating during each on cycle. If a slower flashing frequency is to be used, the duty cycle should be adjusted such that the lamps are on for the longest portion of the time possible that still allows for visible flashing (i.e., the lamp must be given time to visibly blink). Once again, the 7555 must be adequately bypassed to prevent system noise from interfering with duty cycle and frequency. If greater accuracy is desired, a film capacitor may be substituted for the indicated tantalum.

The power FET chosen for this design is an IRF540, which has an $R_{DS(on)}$ of 77 m Ω , but a peak voltage capability of 100 V. It has a peak drain current specification of 110 A maximum, and a continuous drain current specification of 28 A maximum. Although it does have a higher $R_{DS(on)}$ than the IRFZ40, it is a more rugged part in terms of withstanding systems transients and noisy environments. It will require more rigorous heat sinking than the IRFZ40. FETs with higher $R_{DS(on)}$ than the IRF540 are not recommended for this design due to the high peak currents encountered, and the amount of heat that would be generated.

All lamps are flashing in unison in this design; if this is not desirable an inverter can be used in conjunction with the 7555 such that 180 degrees out of phase flashing of two (or more) sets of lamps can be accomplished.

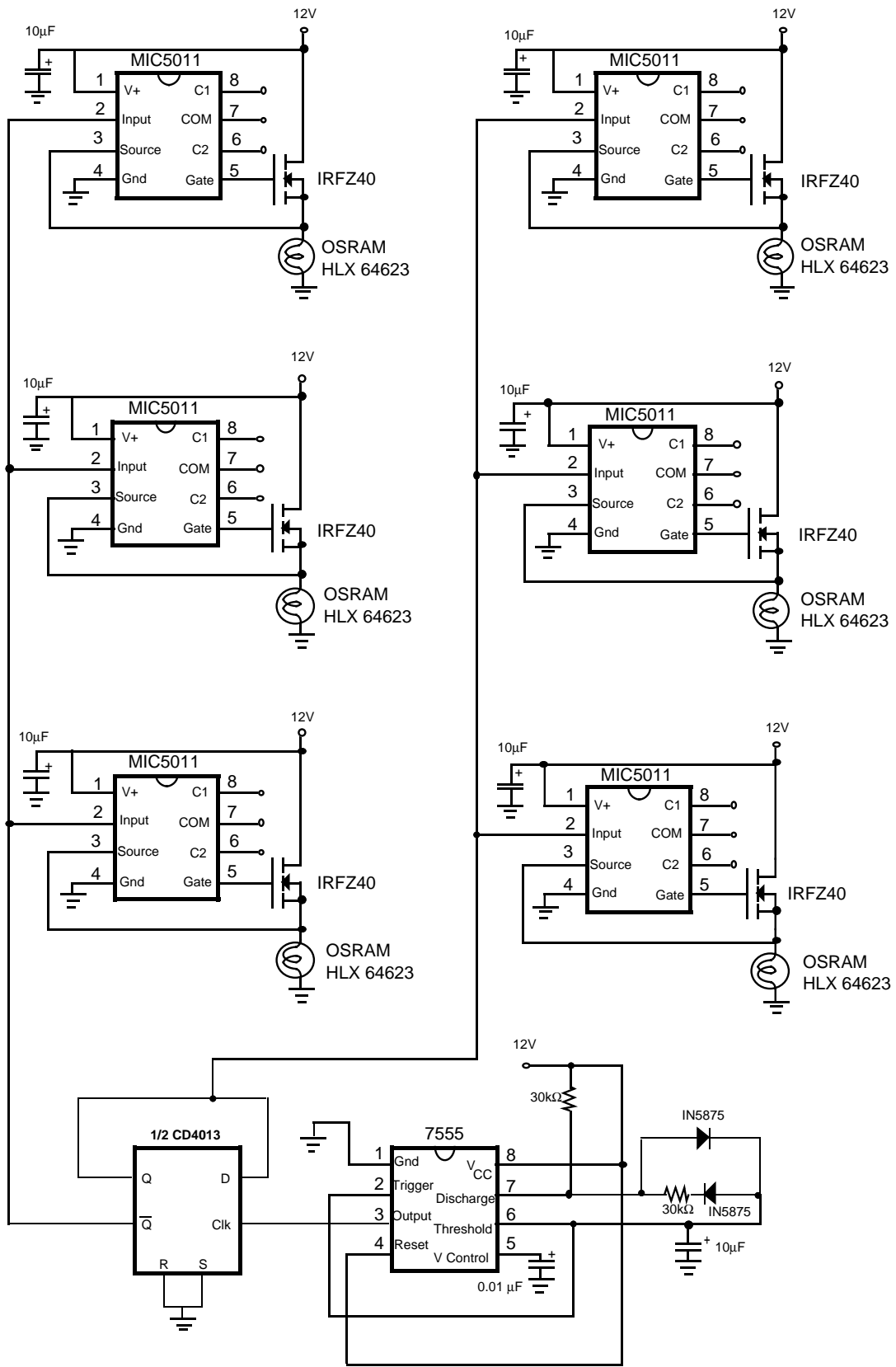


Figure 2: A 75X/Minute, 50% Duty Cycle Halogen Flasher

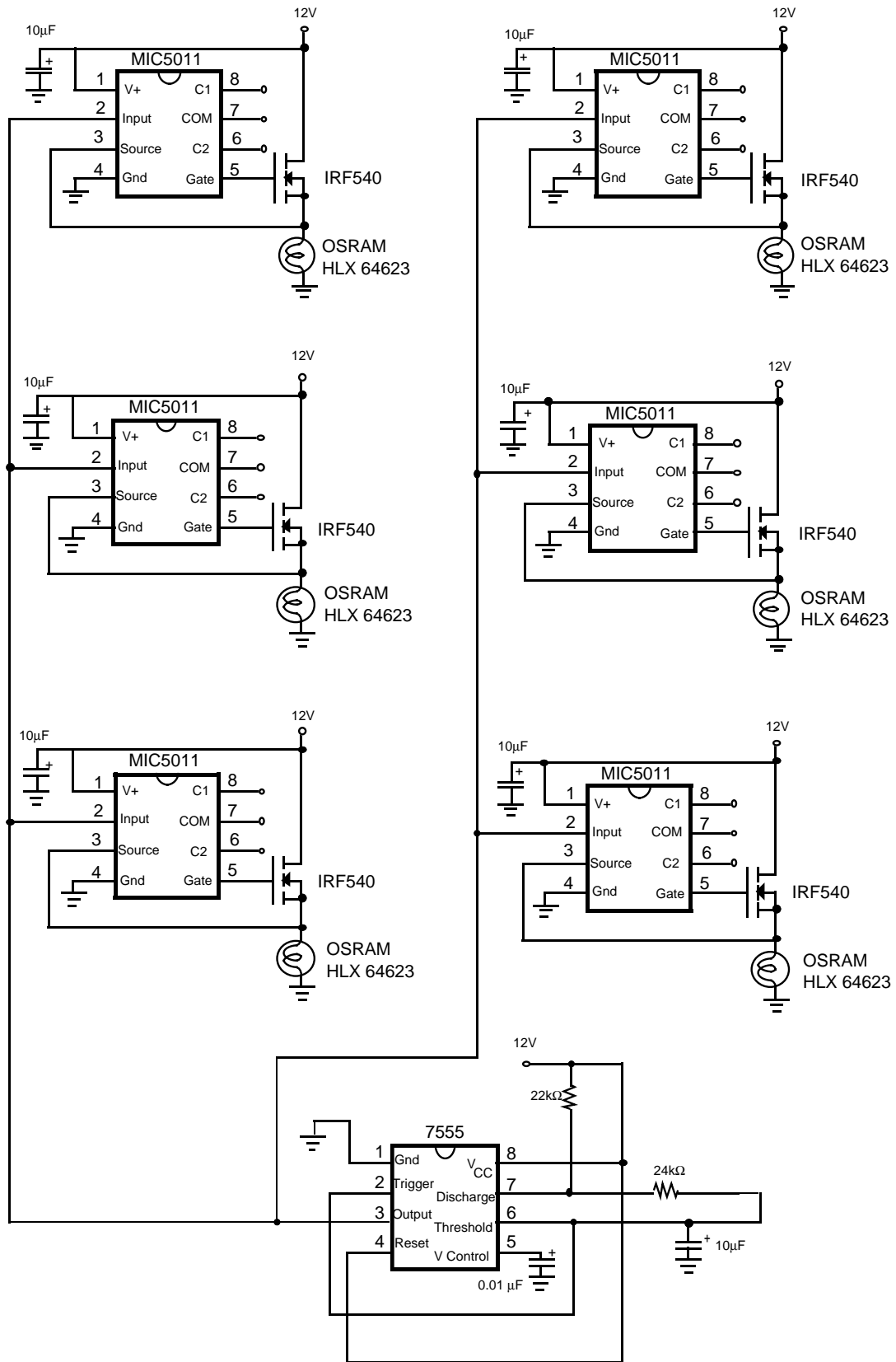


Figure 3: A 120X/Minute Halogen Flasher