More Speed from Optocouplers (Appnote 5)

Figure 1 shows a typical circuit employing an optocoupler to transmit logic signals between electrically isolated parts of a system. In the circuit shown, the optocoupler must "sink" the current from one T^2L load plus a pull-up resistor to V_{CC}. The resistor in series with the LED half of the optocoupler must supply the worst case load current divided by the "current transfer ratio" or CTR of the optocoupler. If an IL1 optocoupler is used, having a minimum CTR of 0.2, and 80 percent variation in the load is allowed, 8.1 mA is required. This is supplied by the 430 Ω resistor.

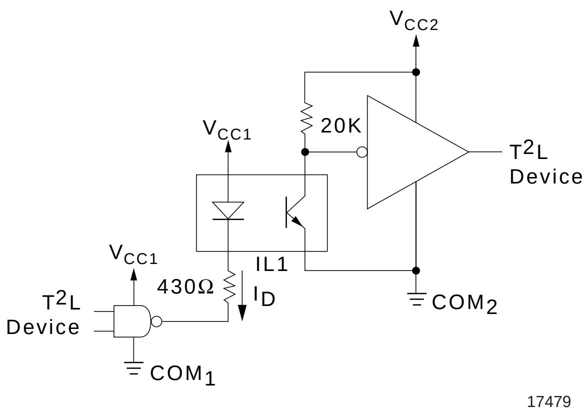

Figure 1.

The maximum repetition rate at which this circuit will operate is only about 8 kHz. The severe speed limitation is due entirely to the characteristics of the phototransistor half of the optocoupler. This device has a large base-collector junction area and a very thick base region in order to make it sensitive to light. C_{ob} is typically 25 pF. This capacitance is, in the circuit of Figure 1, effectively multiplied by a large factor due to the "Miller effect." Also, because the base region volume is large, so is base storage time.

A very simple method of reducing both of these effects is to add a resistor between the base and emitter as shown in Figure 2. This resistor helps by reducing the time constant due to C_{ob} and by removing stored charge from the base region faster than recombination can. When a base-emitter resistor is used, of course, the required LED drive is increased since much of the photo-current generated in the base-collector junction is now deliberately "dumped."

Using this method does not usually result in a large power supply current drain since average repetition rate is low in most applications.

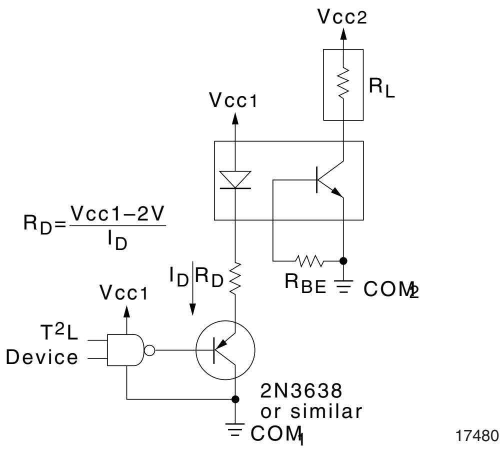

Figure 2.

As drive is increased and R_{BE} reduced, turn-on time and turn-off time both decrease. The total amount of charge stored can also be reduced by decreasing the LED drive pulse duration. Also, as higher drive levels are used, the load resistance, R_L can be reduced to further enhance the speed of the circuit. These parameters are related to each other such that all should be changed together for best results.

One important generalization can be made concerning their interdependence. The LED drive pulse duration, T_{in} output fall time (t_f) output rise time (t_r) and propagation delay (t_p) should occur in a 1.5:1:1:1 ratio, approximately. If this relationship does not occur, the circuit will not operate at as high a repetition rate as it could at the same drive level. T_{out} equals T_{in} at low currents but stretches out at high currents.

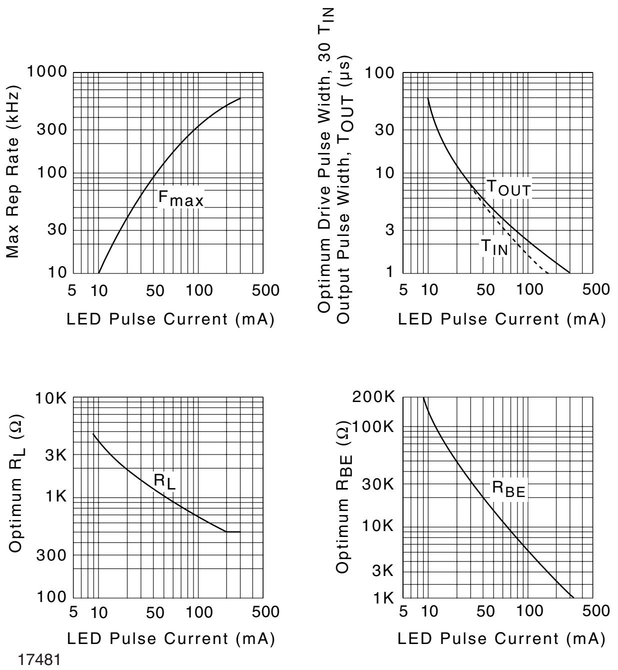

Figure 3. Parameters versus LED pulse current

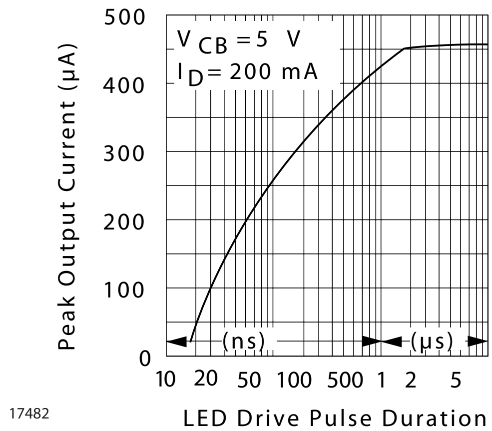

Figure 4. Diode mode output current versus drive pulse duration

Figure 3 is a graph relating the important parameters for a typical IL1 whose CTR is 0.25. The optimum values of T_{in}, R_{BE}, and R_L are shown versus LED pulse current as are the resultant output pulse width and maximum full-swing frequency. Rise, fall and propagation time can be read as $^2/_3$ of T_{in}.

Figure 3 shows that increasing drive to 200 mA and using optimum R_{BE} and R_L will increase the maximum repetition rate from 3 kHz to 500 kHz, a 167:1 improvement.

Lower grade optocouplers will behave similarly if the LED drive level is scaled appropriately to allow for a lower CTR.

Another method of increasing speed is to operate the photo-transistor as a photodiode. In this method, bias voltage is supplied between the collector and base terminal, the emitter being unused. Operation to at least 1.0 MHz is possible this way, but the price is the need for external amplification.

Since output current is small, some type of wide bandwidth amplifier must be employed in order to drive T^2L loads.

One simple solution for intermediate speed operation is the use of MOS inverter (1/6 74HC04),

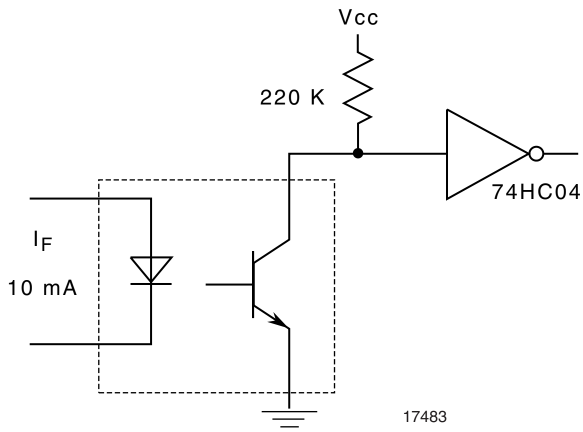

Figure 5.

Another device which will provide a good interface is an integrated comparator amplifier. The phototransistor collector goes to V_{CC}. Its base has a 200 Ω load resistor to ground and goes to one input of the comparator. Also, a resistor goes from this node to the minus supply. This resistor is chosen to supply 50 µA. The other comparator input is grounded. The voltage at the comparator input will switch from –10 mV to + 10 mV or more when the diode turns on and the output will drive the T^2L loads.

Of course discrete component amplifiers could be used and may be best in some applications.

Document Number: 83705
Revision 1.2, 28-Feb-03

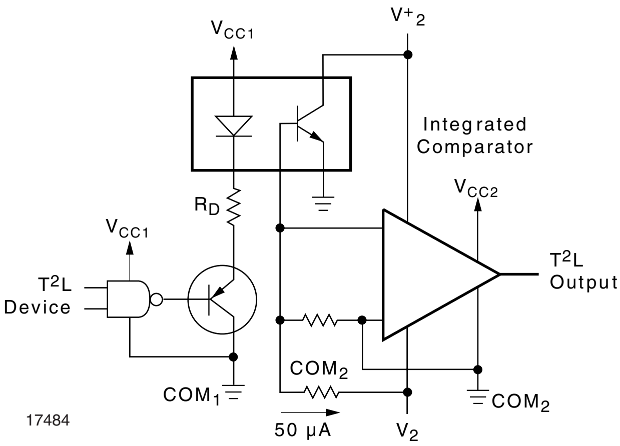

Figure 6.

Conclusion

For operation to 500 kHz, the addition of a base-emitter resistor and a high-current driver is probably the best method of increasing optocoupler speed. Above 500 kHz one must revert to photodiode mode and use an external amplifier to drive most loads, particularly T^2L.