Introducing Microprocessors Part 7

Interfacing LEDs and relays to the parallel port of a microprocessor system.

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In part six we explained some of the virtues of a typical programmable I/O device. Unfortunately, such devices also have a number of shortcomings, not the least of which is associated with the inability to provide sufficient voltage or current drive to an external device or load.

The maximum current which can be sourced from a typical programmable I/O device is limited to about 1mA at a voltage of 1.5V, and clearly this will be inadequate for directly driving all but the most modest of loads; in order to operate external devices such as LEDs or relays an appreciable current or voltage may be required.

LEDs

In order to provide a reasonably bright output, a single LED will generally require a supply current of around 8 to 12mA. Such a current is usually provided by simply wiring a resistor in series with the LED and connecting the resulting series circuit to a supply having a nominal voltage of 5 to 12V. As a general rule of thumb, a typical voltage drop of about 2V appears across an LED in which 10mA is flowing.

Greater light output can be produced from the LED by increasing the forward current and this can be achieved by either reducing the value of the resistor or raising the voltage of the supply (note that it is essential to keep within the manufacturer's recommended maximum ratings for the device). A reduction of light output, on the other hand, can be achieved by increasing the resistance value or reducing the supply voltage.

As an example, let's consider the case of a standard red LED which is to operate from a conventional TTL supply voltage of +5V. The LED would be connected as shown in Fig. 7.1 and the value of the series resistor calculated from the formula:

$R = (5 - Vf)/If$

where Vf is the forward voltage of the diode and If is the forward current.

Assuming that the LED exhibits a normal forward voltage of 2V at a forward current of 10mA, the required value of resistance is thus:

$R = (5 - 2)/0.010 = 300$ ohms

The nearest preferred values are 270 or 330 ohms and a 0.25W resistor of either value will be adequate as the series resistance.

On a rather more practical note, it is essential to observe the polarity of an LED when connecting it into a circuit. Such devices cannot withstand reverse voltages of more than a few volts, and failure to observe this precaution will often result in permanent damage to the LED. The conventional polarity markings for a standard LED are shown in Fig. 7.2.

Relays

Electromechanical relays are available in a wide variety of forms, including miniature dry reed, dual-inline, PCB mounting and plug-in types. Low-voltage DC relays generally have coil resistances between 100 ohms and 3 kilohms and operate from voltages in the range of 3.75V to 24V.

A typical relay for use with a microprocessor system will operate with a current of about 20mA and be capable of switching currents of up to 3A. The characteristics of some representative

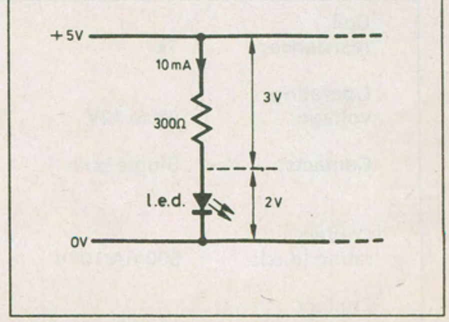

Fig. 7.1. An LED operating from a +5V supply rail.

relay types are shown in Table 7.1.

An important property of a relay is that it can offer very high degree of electrical isolation between the microprocessor system and the controlled circuit. This is particularly important in applications where the controlled circuit is connected directly to the AC supply.

Problem 7.1

An LED is to be operated at the manufacturer's ratings, which are:

Vf = 2.4V and If = 15mA

Assuming that the LED is to be used with a 5V supply, determine the nearest value of the preferred series resistance.

Problem 7.2

A relay has a coil resistance of 700 ohms and requires a nominal operating voltage of 9V. Determine the current required to operate the relay.

Transistor Drivers

The simplest method of interfacing an LED or relay to a parallel I/) port is with the aid of an NPN switching transistor, as shown in Fig. 7.3 and 7.4. Transistors provide current amplification (typically on the order of 50 or more) and are also able to tolerate a much higher load voltage than would be possible with a conventional TTL device.

In the LED driver arrangement of Fig. 7.3, the transistor will be driven into conduction whenever a high level (logic 1) is produced by the port output line. The transistor is operated as a saturated switch, and sufficient base current must be applied for the collector-emitter voltage to fall to a value close to zero. In this condition, the collector current is determined by the supply voltage and the value of the load, rather than by the current gain of the transistor.

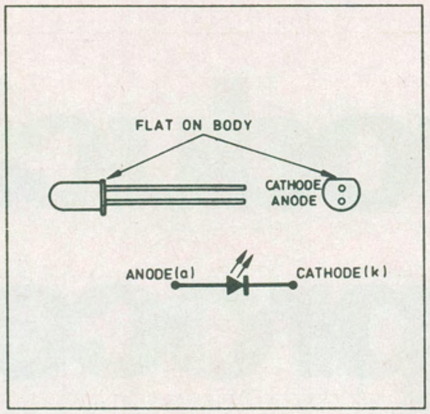

Fig. 7.2. Typical polarity markings for a round LED.

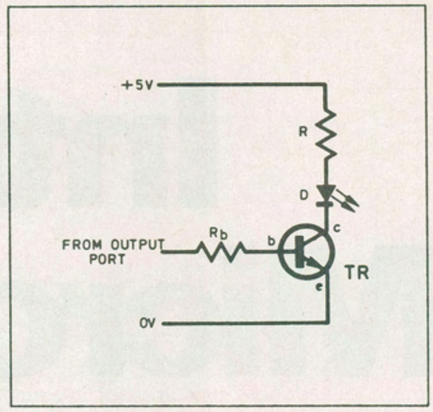

Fig. 7.3. A transistor LED driver.

A base current of approximately 1mA will produce saturated switched with the vast majority of modern silicon transistors, and thus a typical value for the base resistor is 4k7. Fig. 7.5(a) and 7.5(b) show the equivalent circuit of a transistor LED driver in the nonconducting (logic 0) and the conducting (logic 1) states respectively.

The operation of the transistor relay driver in Fig. 7.4. is similar to that of the LED driver in Fig. 7.3; however, an additional diode is connected across the relay coil in order to protect the transistor from the effects of back EMF (the reverse voltage generated by the collapse of the current in the coil inductance whenever the transistor switches off).

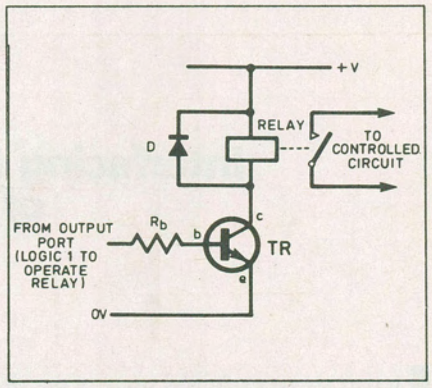

Fig. 7.4. A transistor relay driver.

Open-collector Logic

Another method of increasing the current drive of an output port is with the aid of a TTL buffer. Six identical buffers are usually contained in a single dual-inlinepackage and each device has a single input and output.

Two types of buffer are available: inverting and non-inverting. An inverting

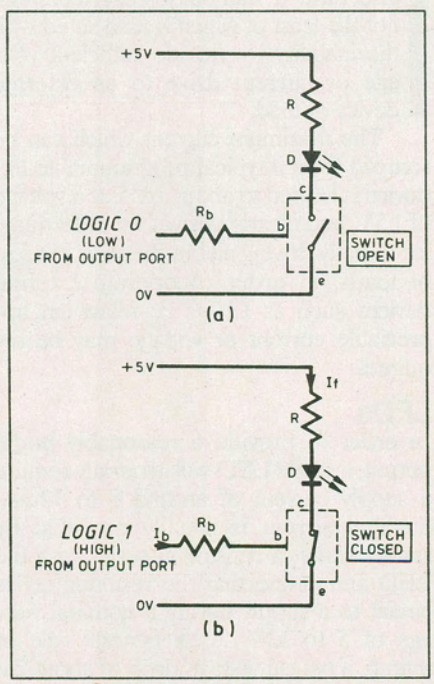

Fig. 5. The equivalent circuit of a transistor LED driver with (a) logic 0 from the output port and (b) logic 1 from the output port.

Table 7.1 Characteristics of some representative relays

Relay type:	Encapsulated reed	Miniature p.c.b.	Plug-in
Coil resistance:	1k	320 ohm	185 ohm
Operating voltage:	9V to 12V	8.4V to 14.4V	8V to 17V
Contacts:	Single pole	Single pole changeover	4-pole changeover
Contact rating (d.c.):	500mA/100V	1A/28V	1A/110V
Contact rating (a.c.):	500mA/120V	500mA/120V	2.5A/120V

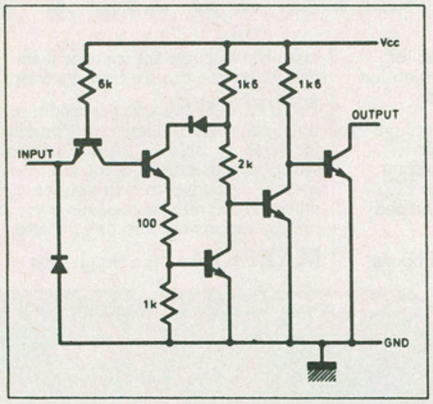

Fig. 7.6. The circuit of a single open-collector TTL inverting buffer (7406 or 7416).

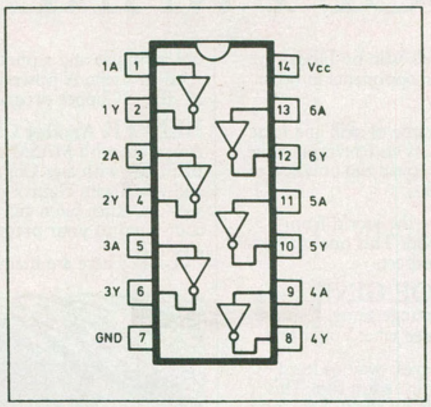

Fig. 7.8. The pin connections for the 7406 and 7416 open- collector inverting buffers.

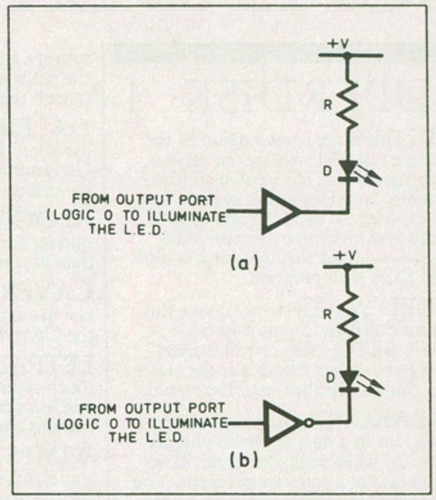

Fig. 7.10. An LED driver using an open-collector TTL gate; (a) a non-inverting buffer (7407 or 7417), and (b) an inverting buffer (7406 or 7416).

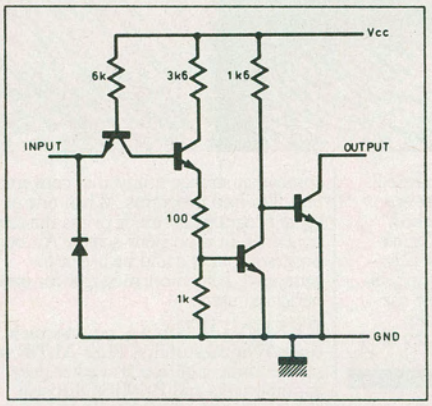

Fig. 7.7. The circuit of a single open-collector TTL non- inverting buffer (7407 or 7414).

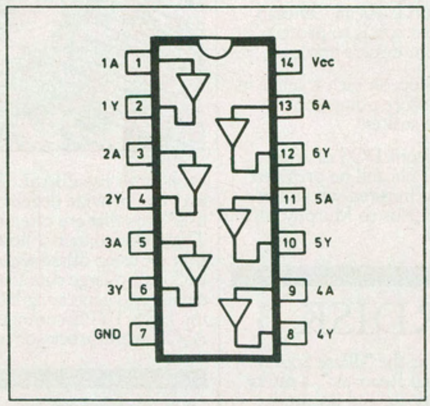

Fig. 7.9. The pin connections for a 7407 and 7417 hex open- collector non-inverting buffer.

buffer produces a low state output when its input is high and high state output when its input is low. A non-inverting buffer, on the other hand, produces a high state output when the input is high and a low state output when the input is low.

Buffers are often fitted with open-collector output stages so that they can be used with external loads in a similar configuration to that adopted with the transistor drivers described earlier. Furthermore, the transistor output stage is usually designed so that the device can tolerate a high supply voltage (note that the early stages of the TTL buffer still require a +5V supply). Details of some typical TTL buffers, both inverting and non-inverting, are given in Table 7.2, while Fig. 7.6 to 7.9 show the circuits and pin connections for two of the most popular types of inverting and non-inverting buffers.

Table 7.2 Characteristics of some typical TTL buffers

Type	Logic function	Load current (max.)*	Load voltage (max.)
7406	Hex inverting buffer (open-collector)	40mA	30V
7407	Hex non-inverting buffer (open-collector)	40mA	30V
7416	Hex inverting buffer (open-collector)	40mA	15V
7417	Hex non-inverting buffer (open-collector)	40mA	15V

*measured with the output in the low state.

Typical LED driver arrangements based on inverting and non- inverting open-collector buffers are shown in Fig. 7.10. Note that the two circuits require logical signals of opposite polarity, and allowance must be made for this in the software routines used to send data to the port.

Representative Output

A representative output driver is shown in Fig. 7.11. Port lines PA0 to PA7 of the programmable parallel I/O device are configured for output. Lines PA0 to PA5 are connected to the inputs of a hex inverting buffer which is used to drive six LED indicators. The remaining port lines, PA6 and PA7, are connected to two NPN silicon transistors which are used as relay drivers.

In order to operate the LEDs and relays, a data byte is written to Port A. As an example, a binary value of 11000111 (hex C7) written to Port A will illuminate the three LEDs connected to PA0, PA1 and PA2, as well as operating the relays connected to PA6 and PA7. To turn the LEDs and relays off, a binary value of 0000000 (hex 00) should be sent to Port A.

Problem 7.3.

Refer to the representative microprocessor output shown in Fig. 7.11.

(a) What data value should be written

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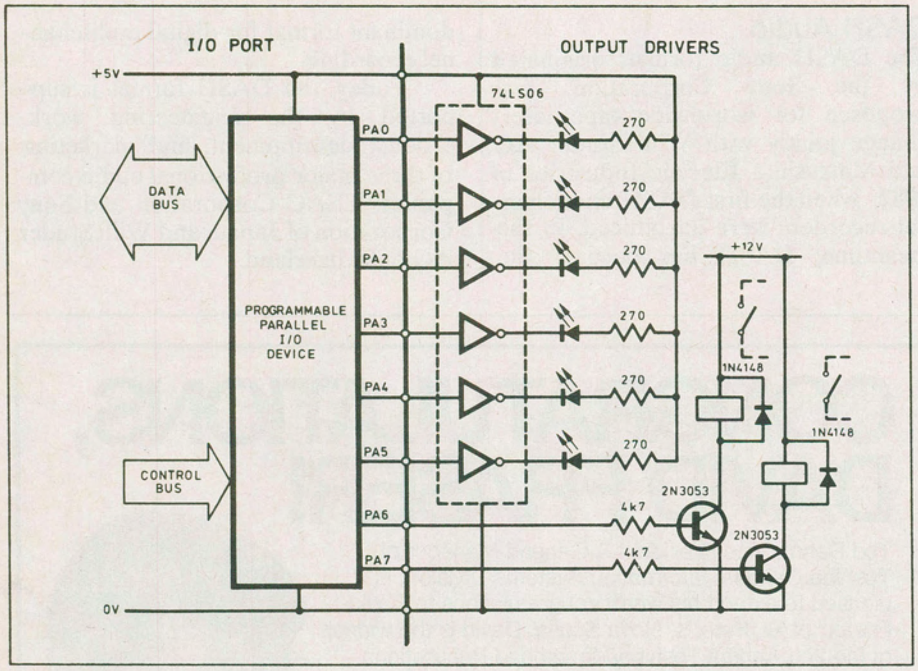

Fig. 7.11. A representative output driver arrangement.

to Port A in order to operate both relays and turn all LEDs off? Express your answer in binary.

(b) What is the hexadecimal equivalent of the value in (a)?

(c) Determine the forward current of an LED when it is operating.

(d) What should be the nominal operating voltage for the relays?

(e) Determine the collector current for the transistors in the conducting (on) state. ■

Answers to Problems

7.1 180 ohms.
7.2. 13mA.
7.3. (a) 11000000
(b) C0
(c) 11mA
(d) 12V
(e) 27mA