'VISIBLE' LIGHT-EMITTING DIODE APPLICATION CIRCUITS

Serial Connection and Parallel Connection

Figure 1 shows the most basic and commonly used circuits for driving light-emitting diodes.

In Figure 1(A), a constant voltage source (V_{CC}) is connected through a current limiting resistor (R) to an LED so that it is supplied with forward current (I_F). The I_F current flowing through the LED is expressed as $I_F = (V_{CC} - V_F)/R$, providing a radiant flux proportional to the I_F. The forward voltage (V_F) of the LED is dependent on the value of I_F, but it is approximated by a constant voltage when setting R.

Figures 1(B) and 1(C) show the circuits for driving LEDs in serial connection and parallel connection, respectively. In arrangement (B), the current flowing through the LED is expressed as $I_F = (V_{CC} - V_F \times N)/R$, while in arrangement (C), the current flowing through each LED is expressed as $I_F = V_{CC} - V_F)/R$ and the total supply current is $N \times I_F$, where N is the number of LEDs.

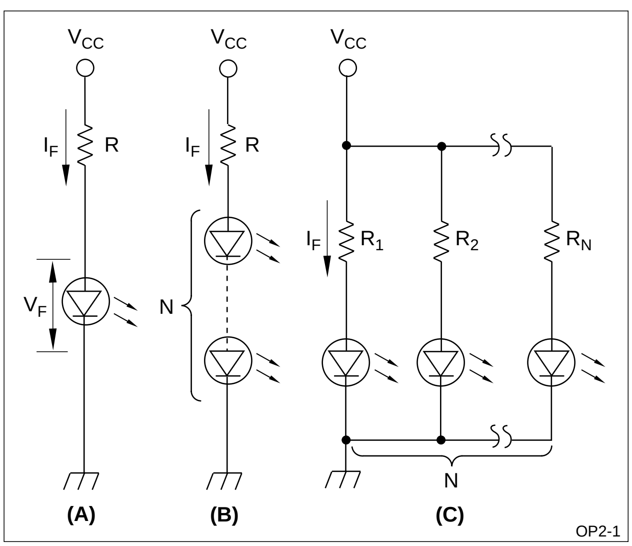


Figure 1. Driving Circuit of Light-Emitting Diode (LED)

The V_F of an LED has a temperature dependency of approximately -1.9 mV/°C. The operating point for the load R varies in response to the ambient temperature as shown in Figure 2.

Constant Current Drive

To stabilize the radiant flux of the LED, the forward current (I_F) must be stabilized by using a constant current source. Figure 3 shows a circuit for constantly driving several LEDs using a transistor. The transistor (Tr_1) is biased by a constant voltage supplied by a zener diode (ZD) so that the voltage across the emitter follower loaded by resistor R_E is constant, thereby making the collector current ($I_C = I_F$) constant. The I_C is given as $I_C = I_E = (V_Z = V_{BE})/R_E$. If too many LEDs are connected, the transistor enters the saturation region and does not operate as a constant current circuit. The number of LEDs (N) which can be connected in series is calculated by the following equations.

$V_{CC} - N \times V_F - V_E > V_{CE}$ (sat)

$V_E = V_Z - V_{BE}$

These equations give:

$N < (V_{CC} - V_Z + V_{BE} - V_{CE}(sat))/V_F$

Figures 4 and 5 show other constant current driving circuits that use diodes or transistors, instead of zener diodes.

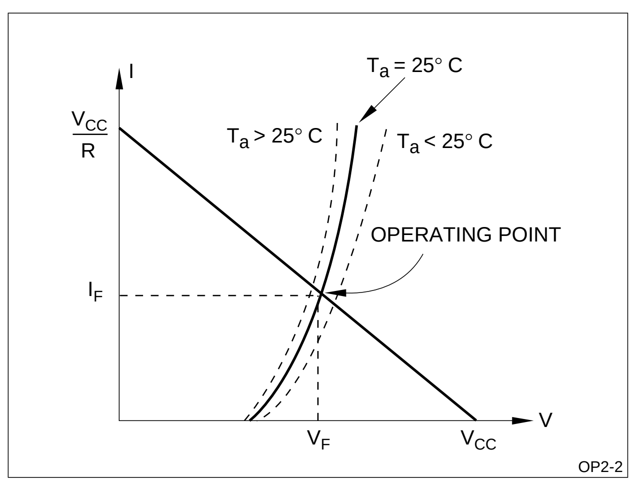


Figure 2. Current vs. Voltage of Light-Emitting Diode (LED)

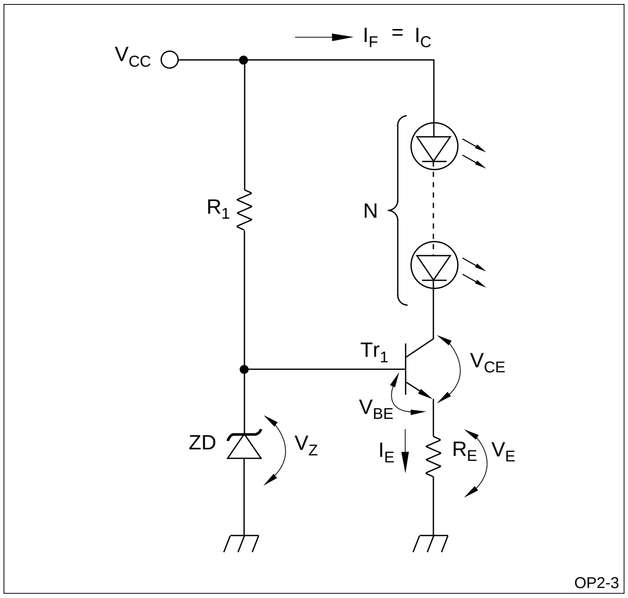


Figure 3. Constant Current Driving Circuit (1)

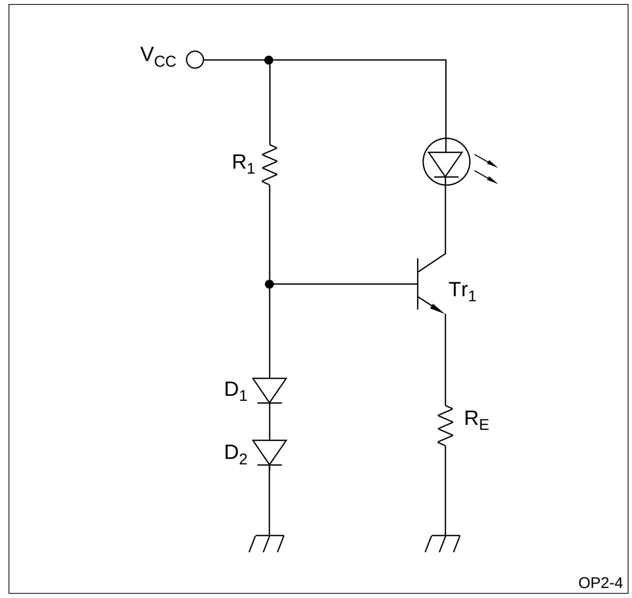


Figure 4. Constant Current Driving Circuit (2)

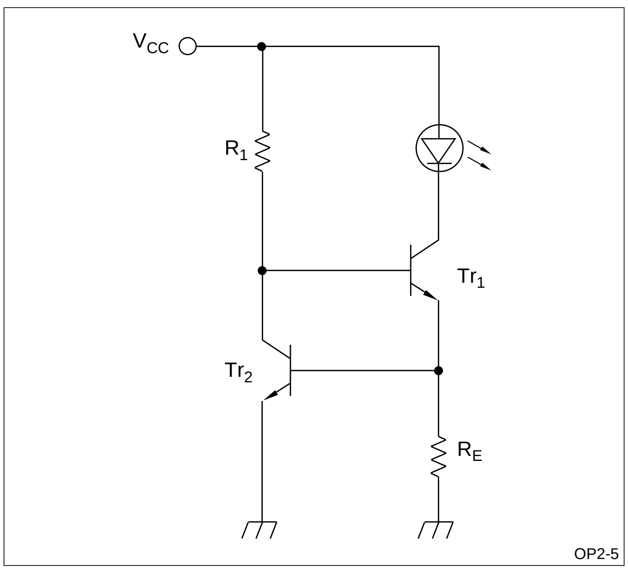


Figure 5. Constant Current Driving Circuit (3)

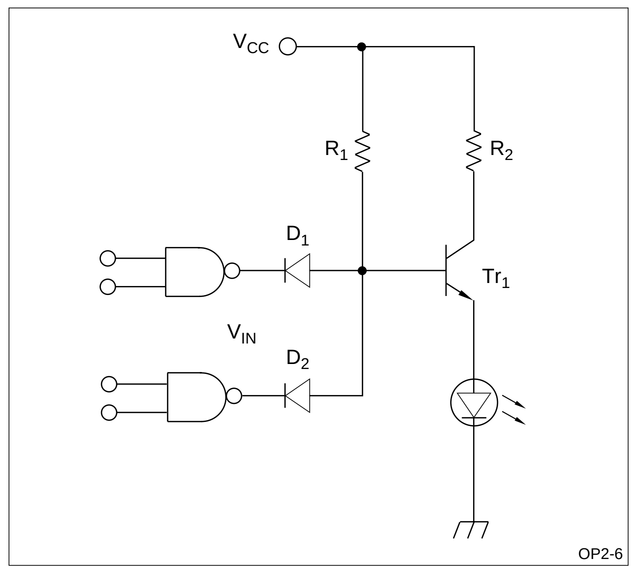


Figure 6. Connection with the TTL Logic Circuit (1)

Driving Circuit Activated by a Logic IC

Figures 6 and 7 show LED driving circuits that operate in response to digital signals provided by TTL or CMOS circuits.

Figure 8 shows a driving circuit connected with a high level logic circuit.

In Figure 6, a high input signal V_{IN} from a TTL circuit makes the NPN transistor (Tr_1) conductive so that the forward current (I_F) flows through the LED. Accordingly, this circuit operates in the positive logic mode, in which a high input activates the LED.

In Figure 7, a low input signal V_{IN} from a TTL circuit makes the PNP transistor (Tr_1) conductive so that the forward current flows through the LED. This circuit operates in the negative logic mode, in which a low input activates the LED.

In Figure 8, the circuit operates in the positive logic mode, and current I_F is stabilized by constant current driving so that the radiant flux of LED is stabilized against variations in the supply voltage (V_{CC}).

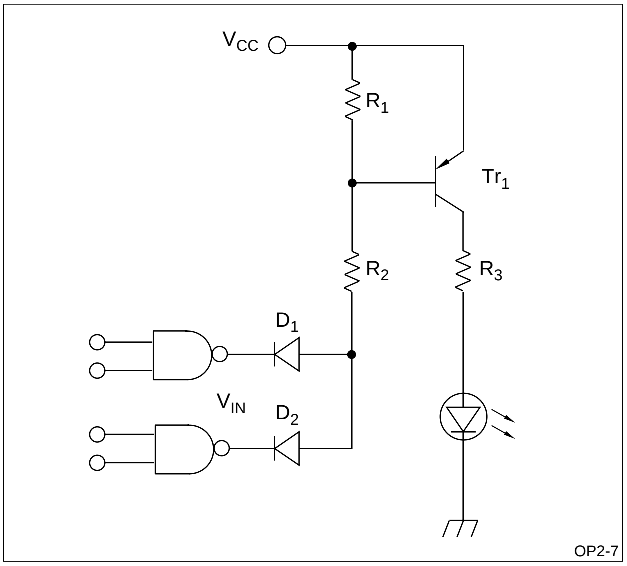


Figure 7. Connection with the TTL Logic Circuit (2)

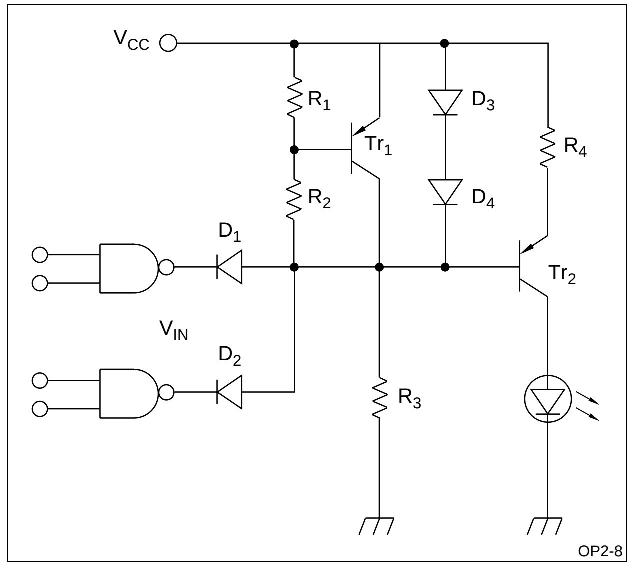


Figure 8. Connection with the TTL Logic Circuit (3)

Driving Circuit with an AC Signal

Figure 9 (A) shows a circuit in which an AC power source supplies the forward current (I_{F1}) to an LED. A diode (D_1) in inverse parallel connection with the LED protects the LED against reverse voltage, suppressing the reverse voltage applied to the LED lower than V_{F2} by using a reverse voltage protection diode of an LED. The LED provides a radiant flux proportional to the applied AC current, (emitting only in half wave).

Figure 9 (B) shows the driving waveform of the AC power source.

Figure 10 (A) shows a driving circuit which modulates the radiant flux of LED in response to a sine wave or modulation signal. Figure 10 (B) shows modulation operation.

If an LED and light detector are used together in an environment of high intensity disturbing light, it is difficult for the light detector to detect the optical signal. In this case, modulating the LED drive signal alleviates the influence of disturbing light and facilitates signal detection.

To drive an LED with a continuous modulation signal, it is necessary to operate the LED in the linear region of the light-emitting characteristics. In the arrangement of Figure 10, a fixed bias (I_{F1}) is applied to the LED using R_1 and R_2 so that the maximum amplitude of the modulation signal voltage (V_{IN}) lies within the linear portion of the LED characteristics. Moreover, to stabilize the radiant flux of the LED, it is driven by a constant current by the constant current driving circuit shown in Figure 3. The capacitor (C) used in Figure 10 (A) is a DC signal blocking capacitor.

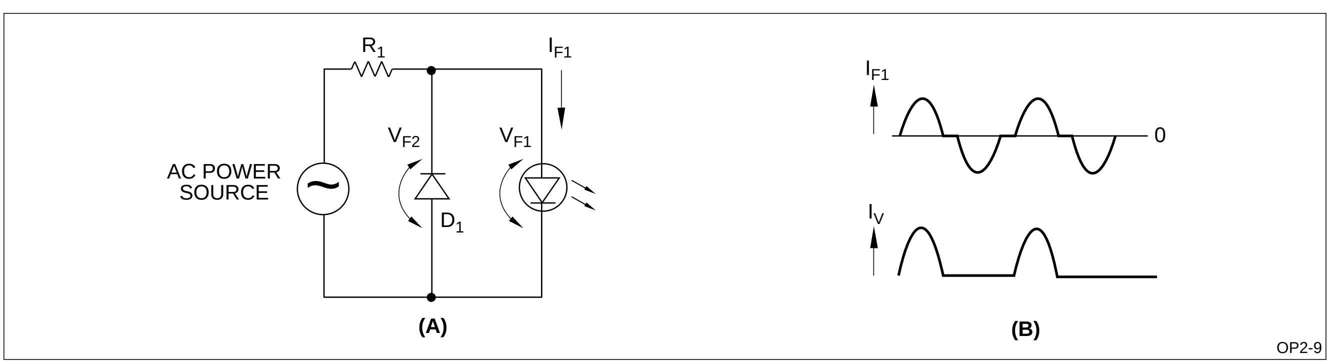


Figure 9. (A) Driving Circuit with AC Power Source
(B) Driving Waveform

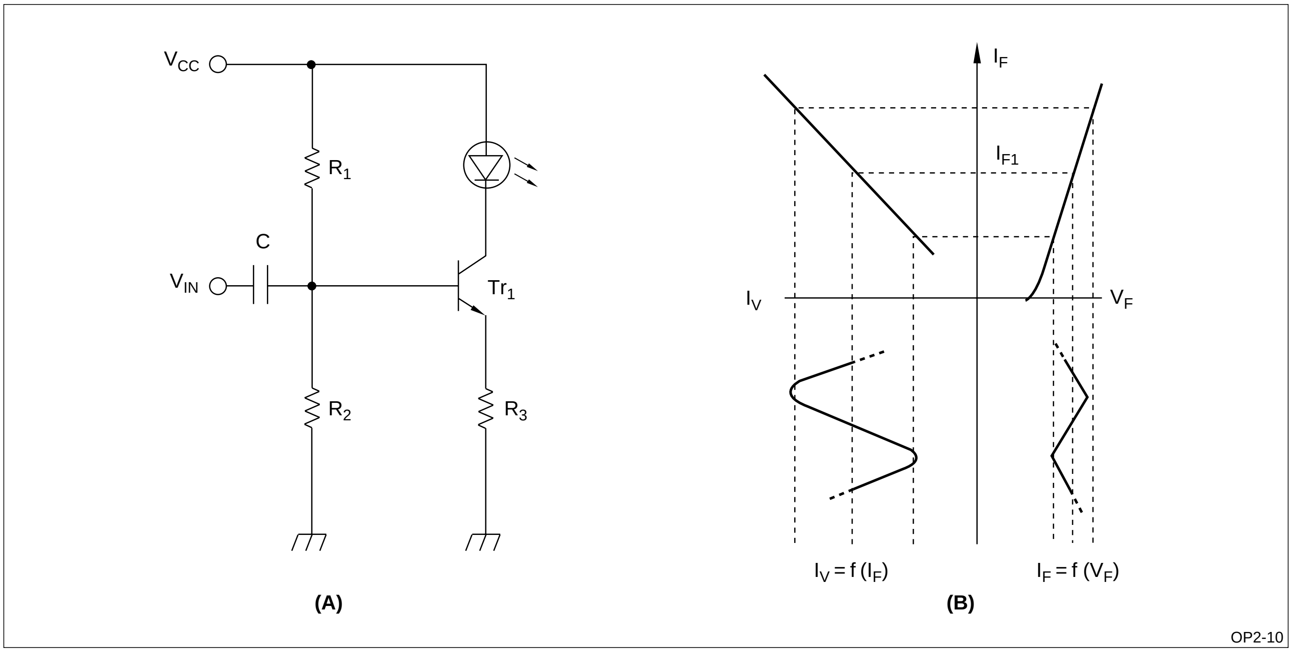


Figure 10. (A) Modulation Driving Circuit
(B) Modulation Operation

Pulse Driving

LED driving systems fall into three categories: DC driving system, AC driving system (including modulation systems), and pulse driving system.

Features of the pulse driving system:

1. Large radiant flux
2. Less influence of disturbing light
3. Information transmission

The radiant flux of the LED is proportional to its forward current (I_F), but in reality a large I_F heats up the LED by itself, causing the light-emitting efficiency to fall and thus saturating the radiant flux. In this circumstance, a relatively large I_F can be used with no risk of heating through the pulse drive of the LED. Consequently, a large radiant flux can be obtained.

When an LED is used in the outdoors where disturbing light is intense, the DC driving system or AC driving system which superimposes an AC signal on a fixed bias current provides low radiant flux, making it difficult to distinguish the signal (irradiation of LED) from disturbing light. In other words, the S/N ratio is small enough to reliably detect the signal. The pulse driving system provides high radiant flux and allows the detection of signal variations at the rising and falling edges of pulses, thereby enabling the use of LED-light detector where disturbing light is intense.

Transmission of information is possible by variations in pulse width or counting of the number of pulses used to encode the LED emission.

Figures 11 through 15 show typical pulse driving circuits. The circuit shown in Figure 11 uses an N-gate thyristor with voltage between the anode and cathode oscillated at a certain interval determined by the time constant of C × R so that the LED emits light pulse. To turn off the N-gate thyristor, resistor R_3 must be used so that the anode current is smaller than the holding current (I_H), i.e., $I_H > V_{CC}/R_3$. Therefore, R_3 has a large value, resulting in a large time constant ($\tau \pm C \times R_3$) and the circuit operates for a relatively long period to provide short pulse widths. The circuit shown in Figure 12 uses a type 555 timer IC to form an astable multivibrator to produce light pulses on the LED. The off-period (t_1) and the on-period (t_2) of the LED are calculated by the following equations:

$$t_1 = 1n2 \times (R_1 + R_2) \times C_1$$

$$t_2 = 1n2 \times R_2 \times C_1$$

The value of R_1 is determined so that the rating of I_{IN} of a 555 timer IC is not exceeded, i.e. $S_1 > V_{CC}/I_{IN}$.

This pulse driving circuit uses a 555 timer IC to provide wide variable range in the oscillation period and light-on time. It is used extensively.

The circuit shown in Figure 13 uses transistors to form an astable multivibrator for pulse driving an LED. The off-period (t_1) of the LED is given by $C_1 \times R_1$, while its on-period (t_2) is given by $C_2 \times R_2$. For oscillation of this circuit, resistors must be chosen so that the R_1/R_3 and R_2/R_5 ratios are large.

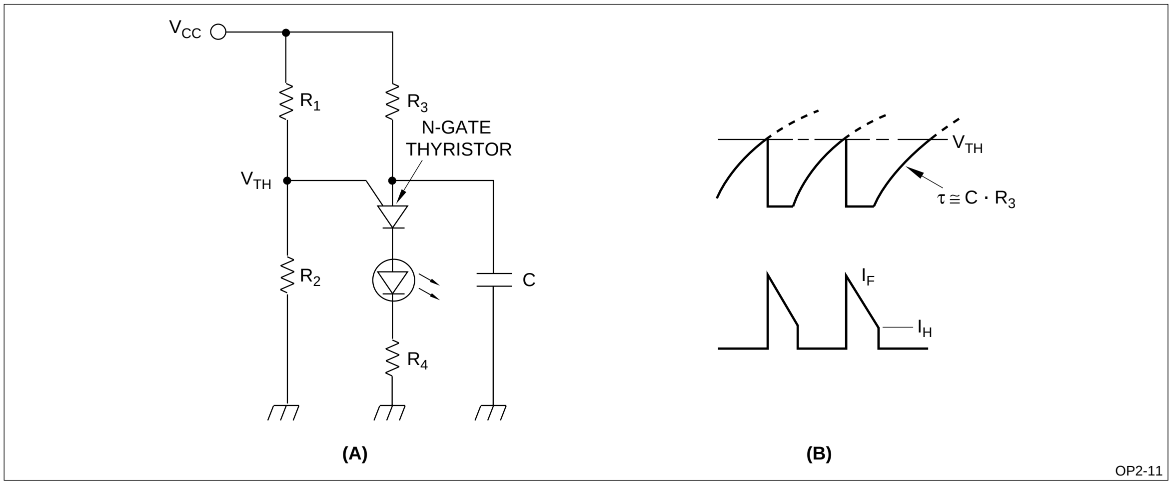


Figure 11. (A) Pulse Driving Circuit using N-Gate Thyristor (B) Operating Waveform

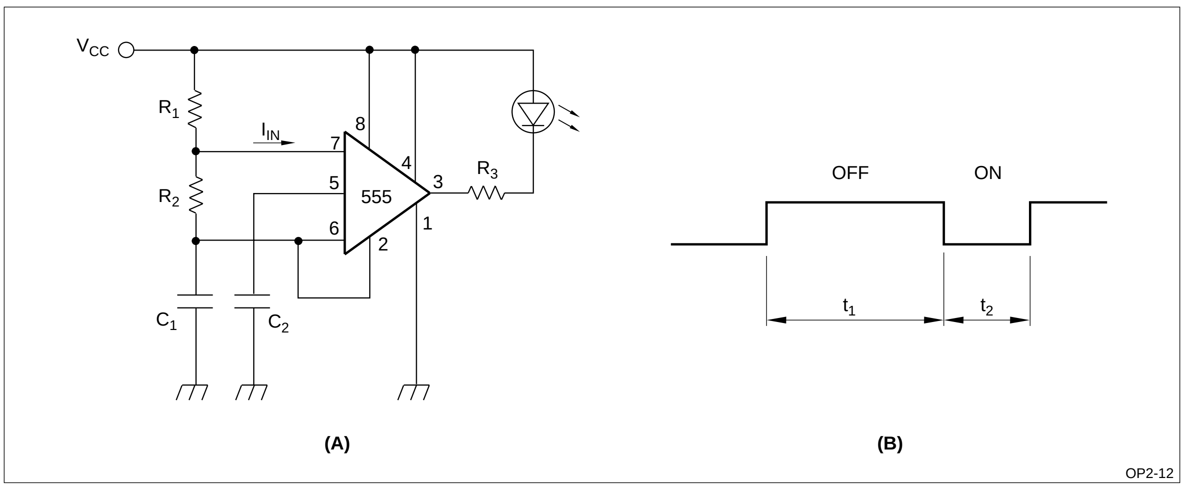


Figure 12. (A) Pulse Driving using a 555 Timer IC (B) Output Waveform

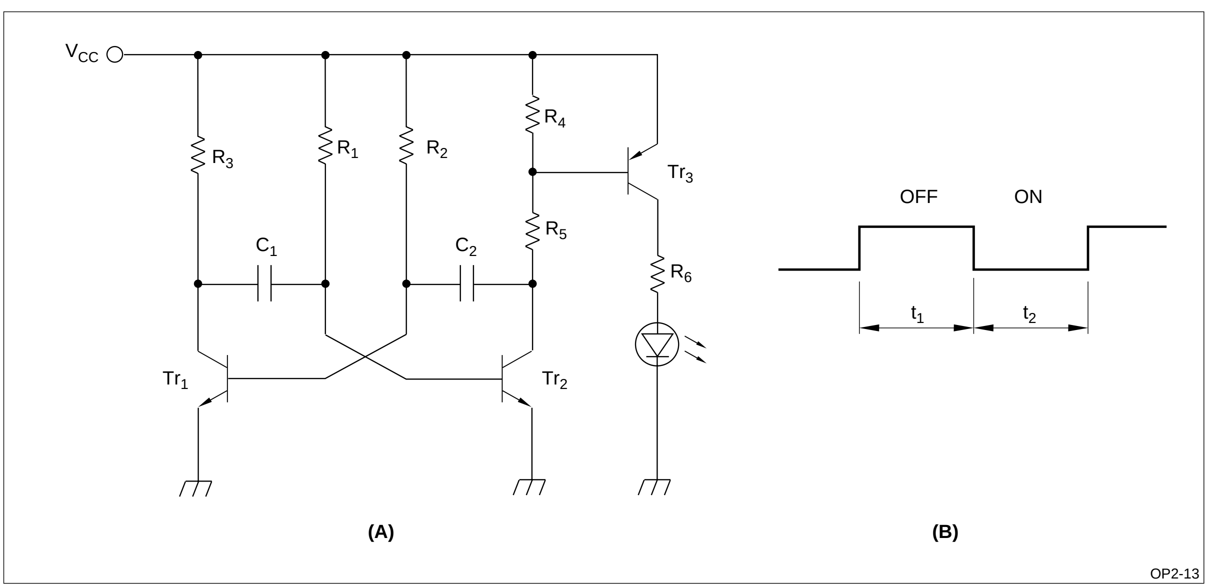


Figure 13. (A) Pulse Driving Circuit using Astable Multivibrator (B) Output Waveform

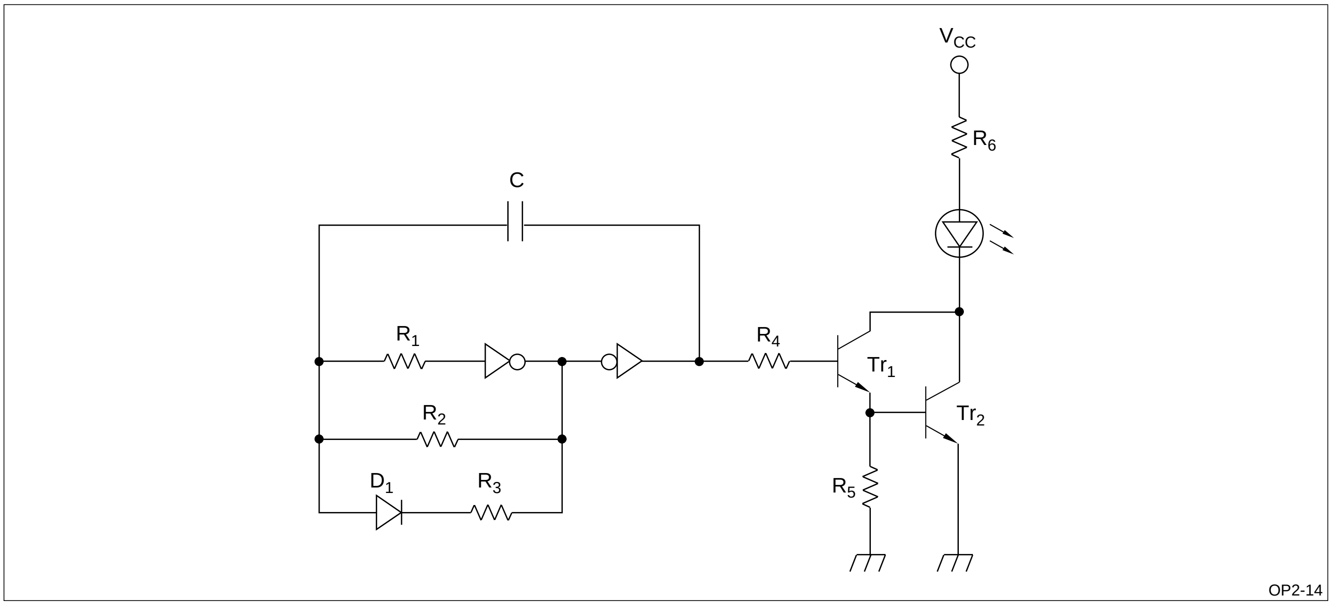


Figure 14. Pulse Driving Circuit using CMOS Logic IC

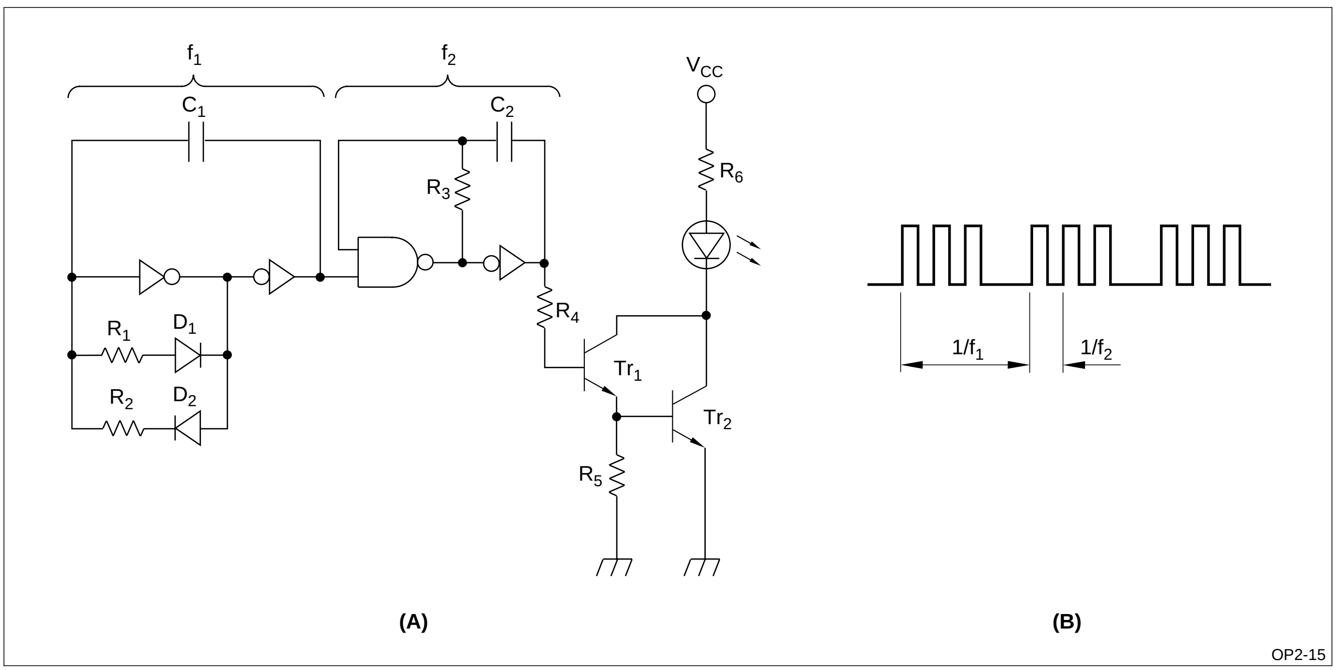


Figure 15. (A) Pulse Driving Circuit
(B) Output Waveform

The circuit shown in Figure 14 uses a CMOS logic IC (inverter) to form an oscillation circuit for pulse driving an LED. The pulse driving circuit using a logic IC provides a relatively short oscillation period with a 50% duty cycle.

Figure 15 (A) shows an LED pulse driving circuit used for the light projector of the optical remote control and optoelectronic switch. The circuit is arranged by combining two different oscillation circuits i.e., a long period oscillation (f_1) superimposed with a short period oscillation (f_2) as shown in Figure 15 (B). Frequencies f_1 and f_2 can be set independently.

Numeric and Symbolic LEDs Driving Circuit

Figure 16 shows an example of a static lighting circuit for a single-digit display. There are two types of pin connections for numeric and symbolic LEDs: the common cathode type, and the common anode type. Driving circuits differ depending on the type.

In practice, the digital display usually has multiple digits in a row, with dynamic lighting by time-sharing. Figure 17 shows an example of the dynamic lighting circuit for a four-digit display, Input signals A, B, C, and D determine numbers 0 to 9; input signals DS1 to DS4 select digit positions.

Figure 18 shows a basic circuit for dynamic lighting. The following equation gives the current (I_{FP}/seg.) that flows through each segment.

$$I_{FP}/\text{seg.} = \frac{V_{CC} - V_{CE(sat)}s - V_F - V_{CE(sat)}d}{R}$$

where,

V_{CC}: Supply voltage

$V_{CE(sat)}s$: Segment driver saturation voltage

V_F: LED forward voltage

$V_{CE(sat)}d$: Digit driver saturation voltage

R: Current limiting resistor

Although pulse peak current increases for greater luminous intensity, care should be taken to set the current limiting resistor to an appropriate value so as not to exceed the maximum rating.

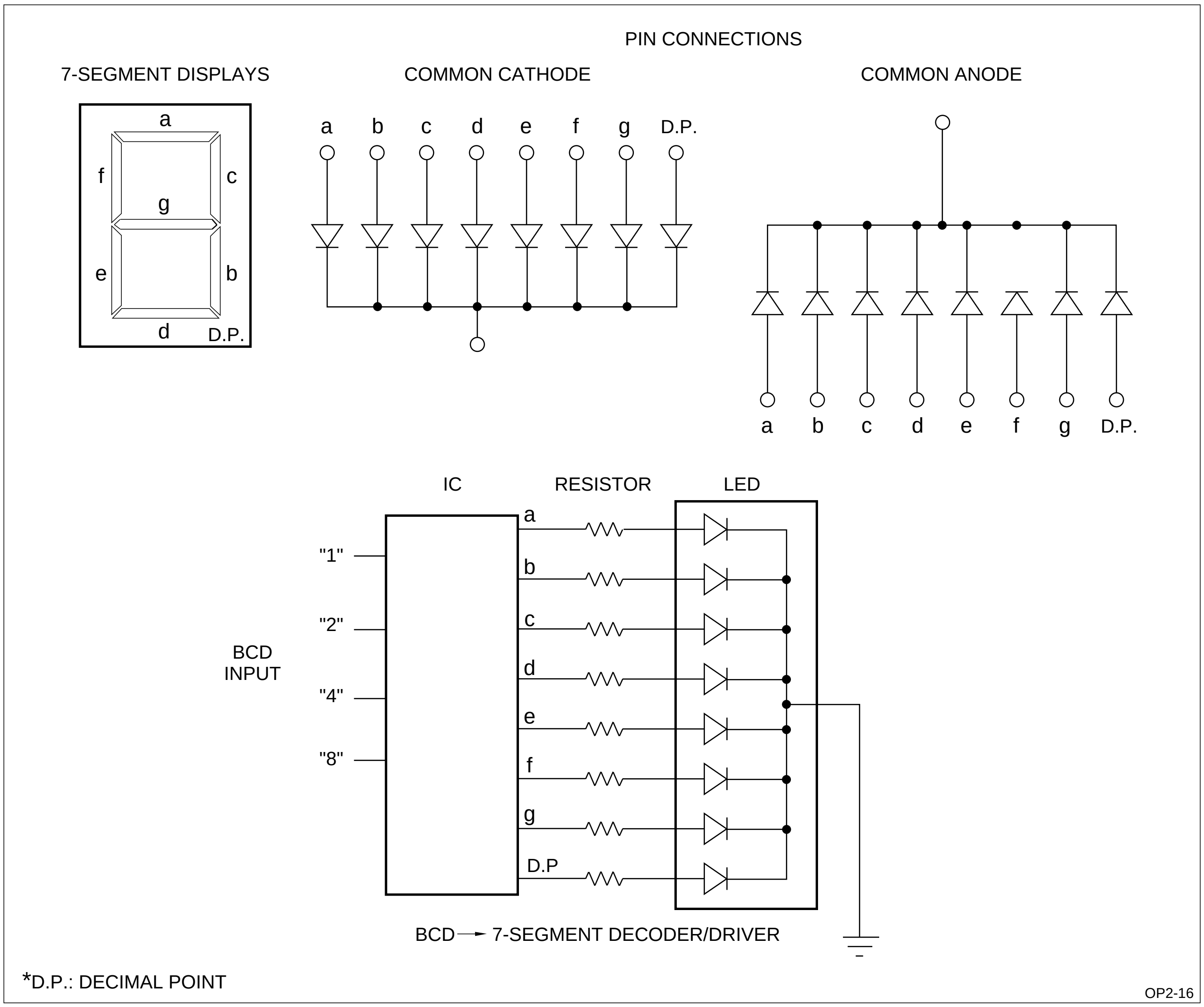


Figure 16. 7-Segment Display Driving Circuit

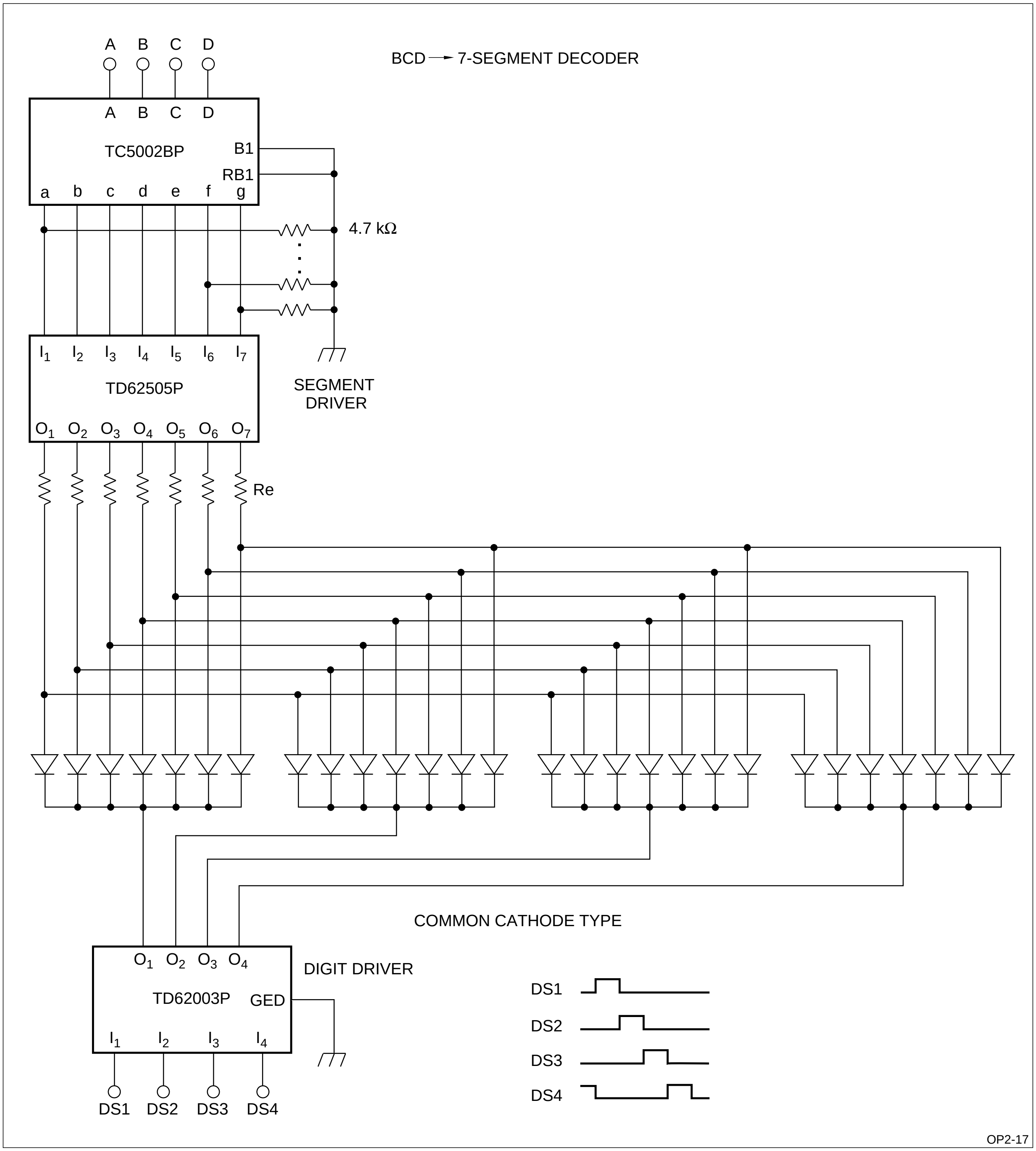


Figure 17. 4-Digit Dynamic Lighting Circuit

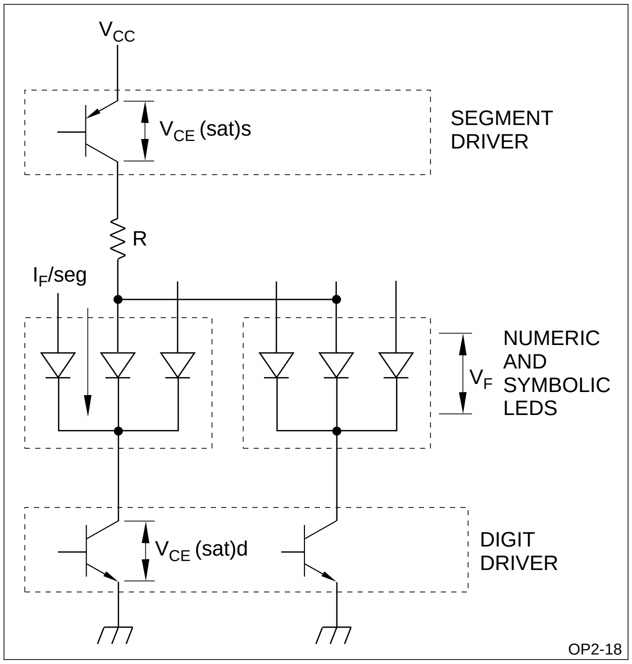


Figure 18. Basic Circuit For Dynamic Driving

Since recent advances in microcomputer technology have brought many types of microcomputer capable of serial signal output, suitable LED drivers were developed. Figure 19 shows an example of such a driver. It has built-in a 32 to 35 bit shift register, a latch circuit and a constant-current output circuit driver for LEDs. One external resistor can vary the current value for all bits. By static operation and with only one chip, this IC can drive a four-digit display. This is very useful. In addition to the digital display, the IC can be used for 5 x 7 dot matrix displays.

Application of Level Meter Circuit

Level meters that indicate voltage, current, temperature humidity or sound volume by bar graphs have advantages such as color coding displacement, quick response and long life. They are used in many fields in place of needle meters. Figure 20 shows an example of a circuit for a 12-dot single row level meter used instead of VU meters in audio systems. It also has a constant-current circuit for output. Therefore, it needs few external components. This makes it easy to use.

In addition, an IC for 5-dot, 2-row and 7-dot, 2-row level meters is also on the market.

Dot Matrix Circuit

Recently, many large information boards using LEDs can be seen on station platforms, in plazas, and on building walls.

In general, 16 x 16 dot or 24 x 24 dot matrix circuits are used for indoor information boards. In many cases, a dynamic driving system is adopted. Figure 21 shows an example. For outdoor use, because display panels must be of greater brightness, static driving systems, as shown in Figure 19, are mainly used.

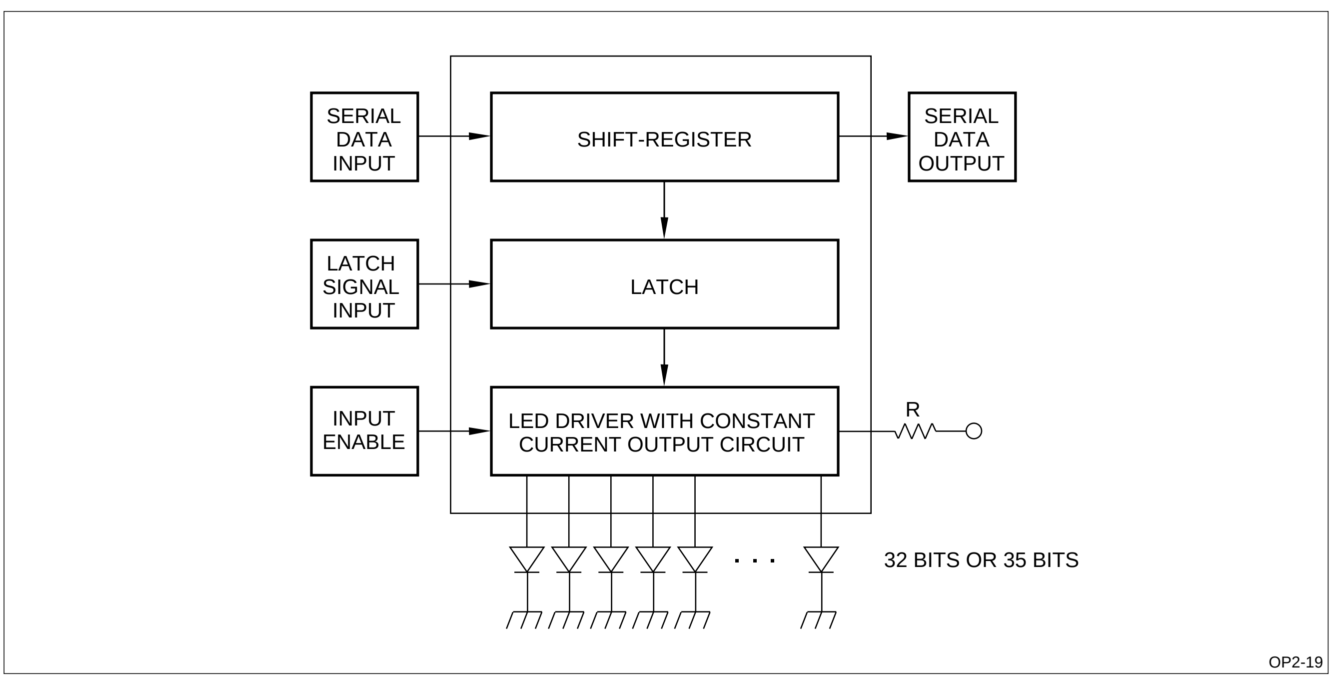
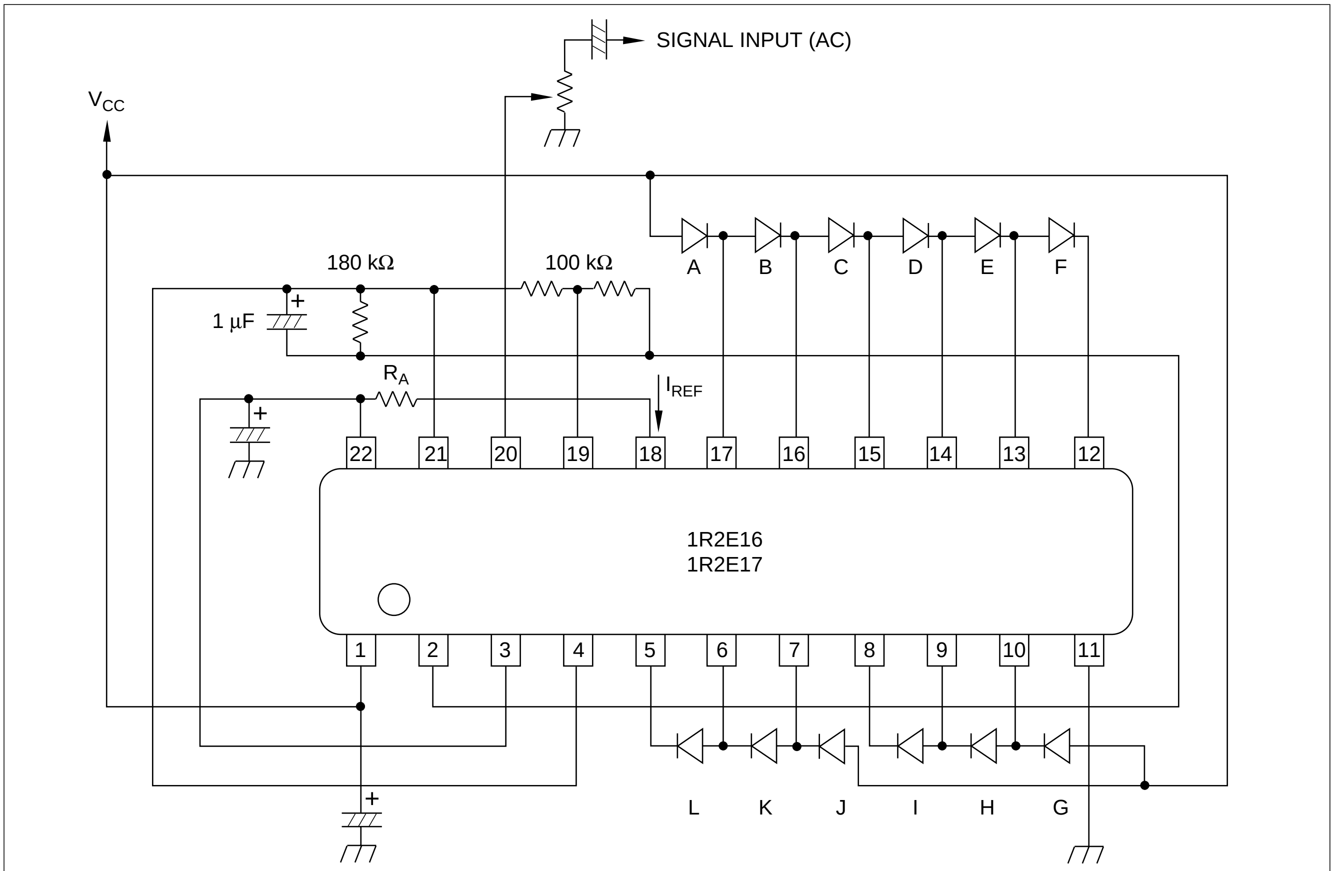


Figure 19. LED Driver with Constant Current Output Circuit



COMPARATOR LEVEL (UNIT: dB)

LED / MODEL NO.	A	B	C	D	E	F	G	H	I	J	K	L
IR2E16	-20	-15	-10	-7	-4	-2	-1	0	+1	+2	+3	+6
IR2E17	-20	-15	-10	-7	-5	-3	-1	0	+1	+3	+5	+8

OP2-20

Figure 20. Driving Circuit using 12-Dot LED

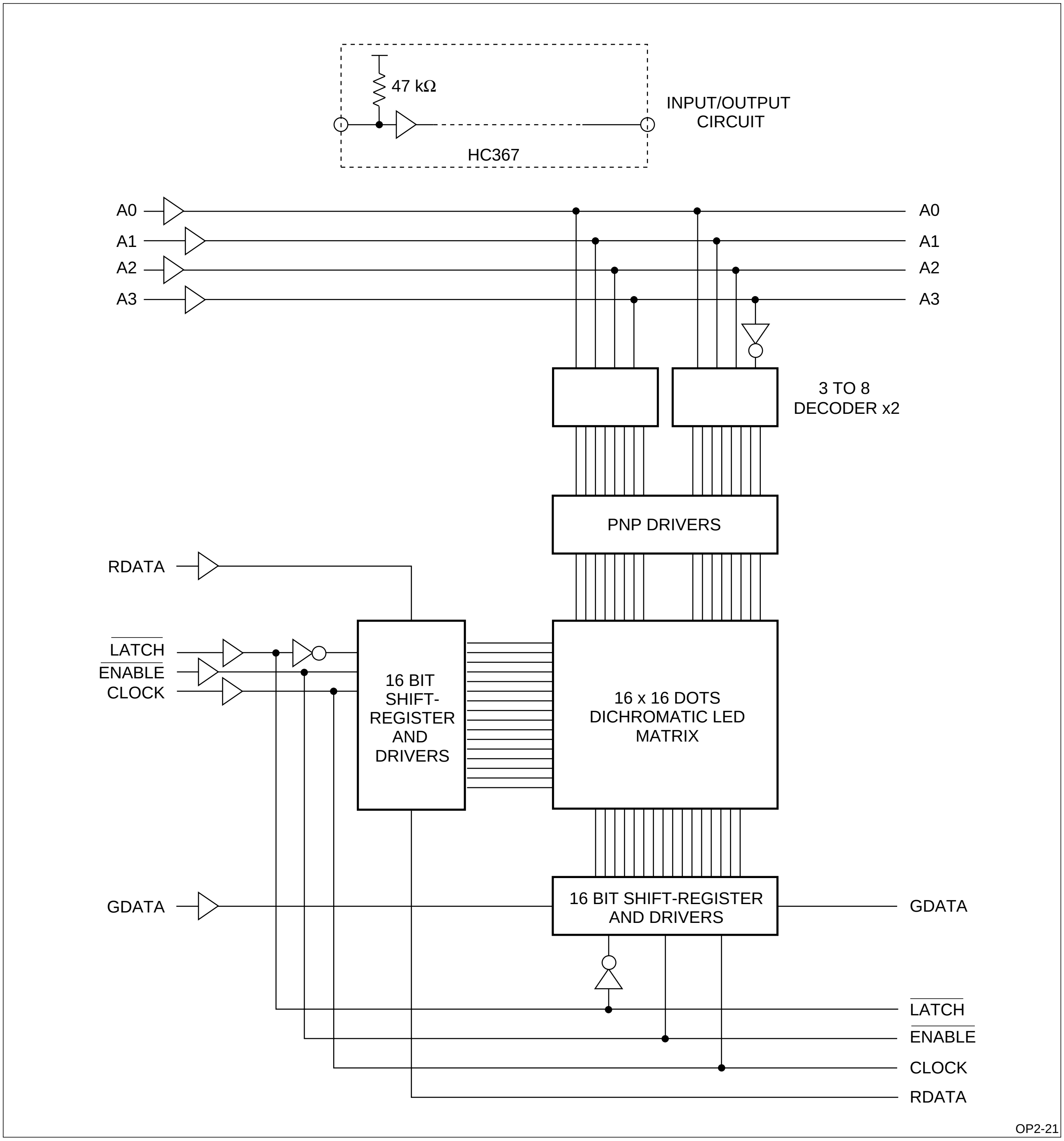


Figure 21. Indoor use of Dot Matrix LED Driving Circuit