Display Driver Family Combines Convenience of Use with Microprocessor Interfaceability

Introduction

For some time now Intersil has manufactured a line of display drivers oriented toward convenience of interface to the displays themselves and to the microprocessor bus or other digital system from which the displayed data comes. These devices have been mainly intended for numeric data (including hexadecimal and similar codes), and have been designed to drive Liquid Crystal (LCD), Light Emitting (LED) and Vacuum Fluorescent (VF) displays. Most have offered full-time drive, limiting the total number of segments that could be driven by each device to 28. The recent growth in popularity of alphanumeric displays, fueled by intelligent typewriters, language translators, Point of Sale Equipment, intelligent test equipment, and so on, has led to the development of a series of alphanumeric display drivers for LCDs and LEDs. The large number of segments involved means that any useful multi-character driver must use a multiplexing scheme, and fortunately LCD technology has reached a point where suitable multiplexable fluids are now becoming widely available. As for LEDs, the circuit and layout technology to handle the higher currents involved in a suitable LSI process has also been developed at the right time. A brief glance at the earlier products will lead us to a closer look at these new display drivers.

Advantages of IC Drivers

Decoding and driving circuits for various types of numeric and alphanumeric displays have been greatly simplified by large scale integration. These new display drivers dramatically exhibit the following benefits and advantages over discrete designs:

- more circuit functions in less space
- simpler design effort for the user
- more flexible operation
- reduced circuit expense

Consider, for example, the design of an ASCII 8-character alphanumeric multiplexed LED display system. The block diagram for such a system constructed with discrete and MSI components is shown in Figure 2. Included as one of the blocks is an 8 word by 6-bit memory which stores the 6-bit ASCII word for each of the characters to be displayed. The addresses for the memory are selected either from the input circuitry, when writing to the display, or from the 3-bit counter, which generates the addresses for the 3 line to 8 line decoder. The NPN transistors drive the common cathode display for each character. The data from the memory is sent to a decoder which determines the correct segments to be turned on and must be a specially programmed ROM or PLA with an output for each of the 14- or 16-character segments. The PNP transistors serve as individual segment drivers, and the resistors in each of their collectors serve to set the current for that segment.

By contrast, Figure 1 shows an ASCII 8-character alphanumeric multiplexed LED display system in which all of the decoding, multiplexing, and driving is accomplished by a single integrated circuit, Intersil's ICM7243. The savings in board space, design time by the user, and cost are easy to see. Additionally, this single chip approach offers several additional features, such as built-in microprocessor compatibility, low power shutdown mode, and automatic interdigit blanking. These features would require extra circuitry in the discrete design and increase the cost of the system.

One advantage frequently not fully appreciated is the off-loading of microprocessor software into the display driver. This can free up both memory and time for other tasks, as compared to designs using software-derived display decoding and timing.

The integrated circuits now available provide a wide selection of display driving capability and can be divided into several categories. Most numeric display drivers also provide a few alphabetic characters for displaying hexadecimal values. True alphanumeric display devices have numbers, letters, punctuation marks, and other symbols in their character sets. The interconnection to display driver ICs also varies from multiplexed BCD inputs to serial bit-stream arrangements or parallel microprocessor bus compatible input schemes.

Non-Multiplexed Displays

One important category of driver circuit is the non-multiplexed, or direct drive type. In this case, direct drive means that there is one line for each segment of the display (e.g., 4 digits x 7 segments = 28 lines).

In many applications the use of a full-time or non-multiplexed configuration has a number of advantages. For relatively high current displays such as LEDs and VF, the absence of continuous and somewhat unpredictable display current changes can be a major advantage. Current spikes and level changes, reflected usually on supply lines to other circuitry, are minimized, and generally occur only when the display is changed, thus being under the control of the rest of the system. As for LCDs, multiplexable displays, though widely used in calculators, have not been available on the general market.

The IMC7211, ICM7212 and ICM7235 series of full time display drivers come in a number of versions. The ICM7211 drives liquid crystal displays (LCD), the ICM7212 drives light emitting diode displays (LED) and the ICM7235 drives vacuum fluorescent display panels (VF). These three display drivers are identical except for the output driver structure. Multiplexed BCD

or microprocessor bus compatible input configurations are available. As shown in the Functional Diagram of Figure 3, they all drive 4 digits of 7 segments each. The data input is fed through a decoder into the latch, from which the segment outputs are derived. This particular part is an LCD driver, and so includes a backplane oscillator and driver, which is also fed to the segment drivers. The oscillator is arranged so that the backplane driver can be disabled by tying the oscillator pin to the negative supply. Once this is done, the associated pin, together with the segment drivers keyed from it, can then be externally driven. Several display drivers can thus drive a multidigit display, with one backplane. The digit into which the incoming data is loaded is determined by individual select lines, for ready interface with the multiplexed BCD signals widely used in instrumentation, etc.

Another version is shown in Figure 4. This part, the ICM7121M is oriented to microprocessor bus interface, with binary-coded digit select lines and active low $\overline{\text{CHIP}}$ $\overline{\text{SELECT}}$ lines. The device is an LED driver, and the backplane oscillator and control is replaced by a brightness control.

The output is set to drive common anode displays, with segment currents of typically 8mA. The Functional Diagram of the ICM7335M VF display driver is virtually identical, except for the polarity of the outputs. These outputs can withstand up to 30V when off, more than adequate for the standard VF displays available. The segment current is typically 2.5mA, which also allows the devices to be used for driving common cathode LEDs.

Another variation in this family of parts concerns the display font. The 4 line binary input data is decoded to 7-segment format in mask programmable ROM, allowing any pattern to be constructed, and if desired separate decodes can be

arranged for each digit. Two standard patterns are provided, as shown in Table 1. The hexadecimal code is widely used in microprocessor and other binary digital systems, while "Code B" is popular in instruments and equipment where certain test and warning messages can be provided readily. Both provide standard BCD decoding for numerals.

Some typical applications of these devices are shown in the next few figures. Figure 5 shows the ICM7211 interfaced to the ICL7135, a new single chip $4\frac{1}{2}$ digit A/D converter. This device provides a multiplexed BCD output, together with polarity and overrange information. The circuit shown uses a CD4054 to drive the half digit, polarity, and overrange flags. A similar circuit for driving VF displays is shown in Figure 6, using the ICM7235. Brightness control is achieved by pulsed duty cycle using a CMOS 7555 timer on the ON/OFF input. The identical circuit (with a lower display voltage) can be used with common cathode LEDs, while substituting an ICM7212 will allow the use of common anode LEDs.
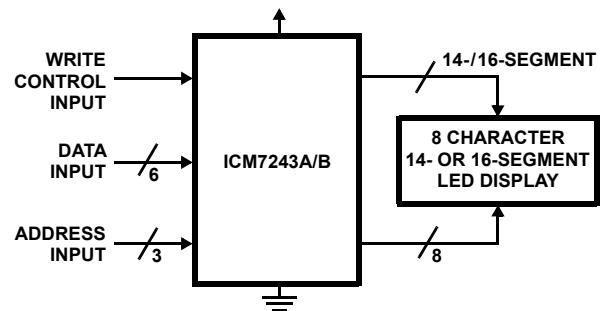

FIGURE 1. 8-CHARACTER ALPHANUMERIC LED DISPLAY SYSTEM (SINGLE CHIP DESIGN)
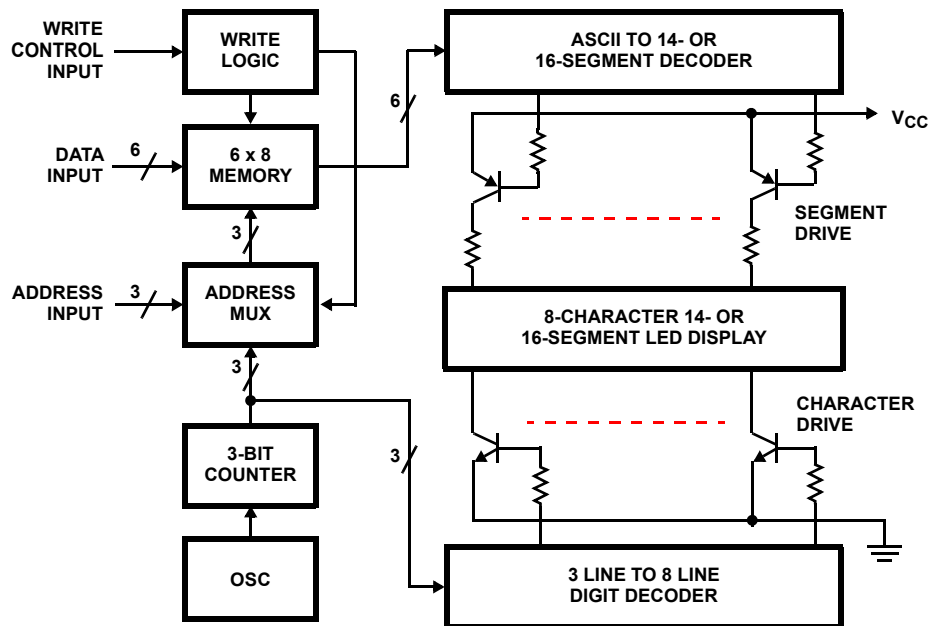

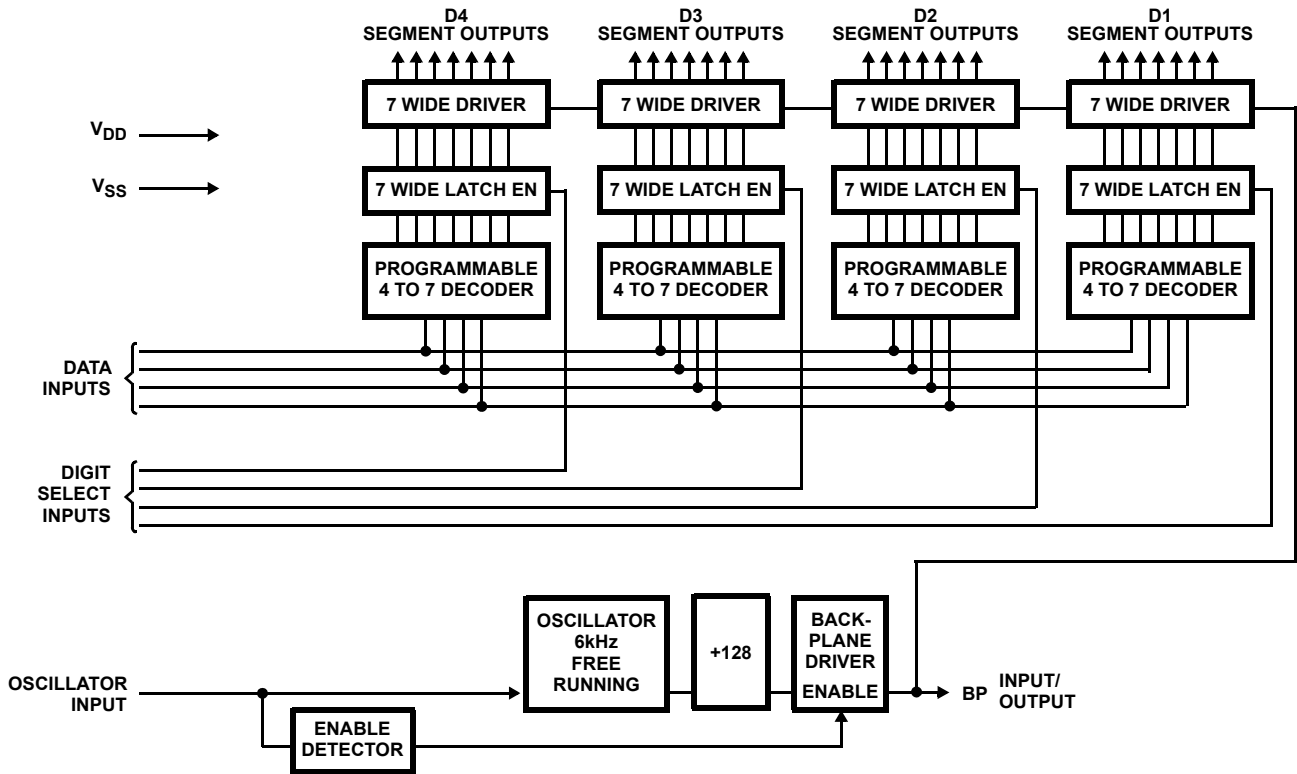**FIGURE 2. 8-CHARACTER ALPHANUMERIC LED DISPLAY SYSTEM (DISCRETE DESIGN)**

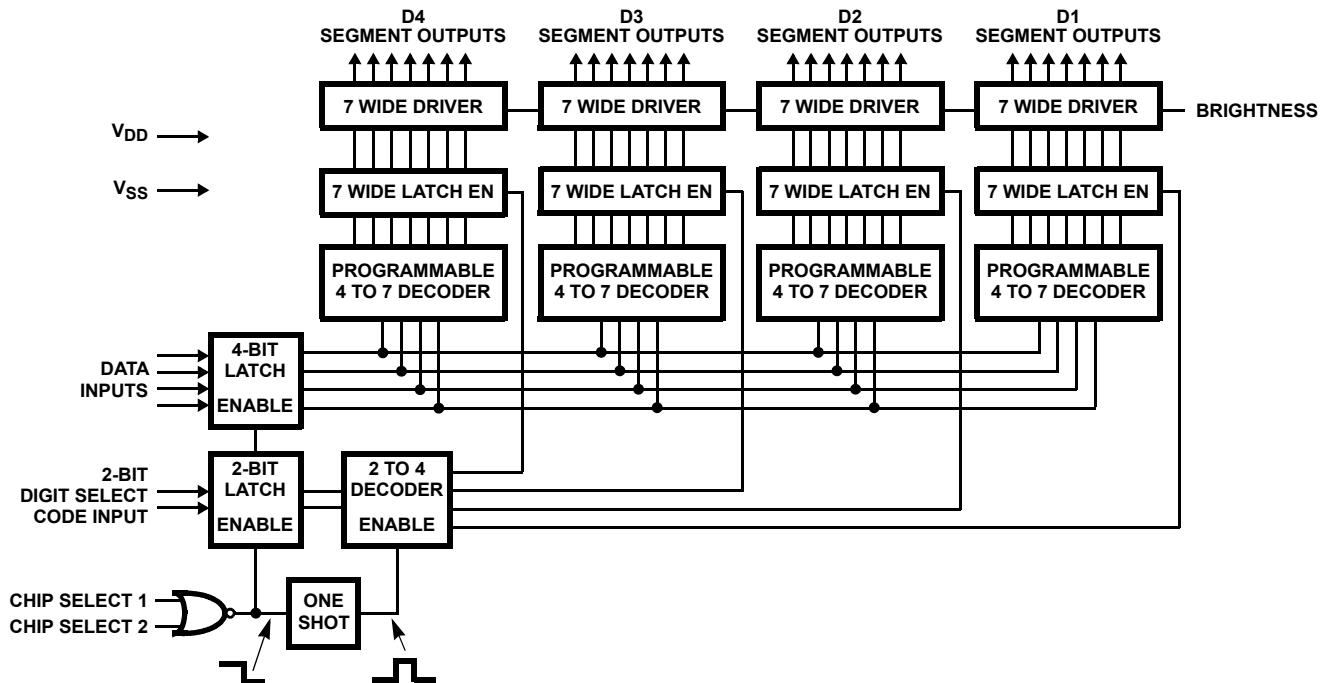RENESAS

FIGURE 3. FUNCTIONAL DIAGRAM OF ICM7211

FIGURE 4. FUNCTIONAL DIAGRAM OF ICM7212M/ICM7235M

Figure 7 shows a pair of ICM7211M devices set up on an 8048 bus and accessed by port lines to form an 8-digit LCD display for a microcomputer based system. In this arrangement, any digit can be changed independently from the others and the display used for system values in decimal or hexadecimal notation. The lines B_0-B_3 are the data input lines of the display drivers; data on these lines is decoded from BCD to 7-segment format when the chip select (CS_1 and CS_2) conditions are met for that device. The digit to be written is determined by the select lines, DS_1 and DS_2. The 56 segment drive lines from the two ICM7211s are synchronized by use of the OSC INPUT (pin 36) on the right-hand ICM7211. When this pin is tied low, the backplane output (pin 5) is transformed into an input and can be driven by the backplane output of the lefthand ICM7211. In this way a single 8-digit LCD display with one backplane connection can be driven by two LCD display drivers.

TABLE 1. OUTPUT CODES FOR 7-SEGMENT DISPLAYS

BINARY				HEXADECIMAL ICM7211(M) ICM7212(M)	CODE B ICM7211A(M) ICM7212A(M)
B3	B2	B1	B0		
0	0	0	0	0	0
0	0	0	1	1	1
0	0	1	0	2	2
0	0	1	1	3	3
0	1	0	0	4	4
0	1	0	1	5	5
0	1	1	0	6	6
0	1	1	1	7	7
1	0	0	0	8	8
1	0	0	1	9	9
1	0	1	0	A	-
1	0	1	1	B	E
1	1	0	0	C	H
1	1	0	1	D	L
1	1	1	0	E	P
1	1	1	1	F	(BLANK)

A similar interface can easily be designed for MCS-80/85/86 systems and the Motorola MC680X and MOS Technology/Rockwell MCS650X devices. Although the LCD devices are shown, the same arrangement can also be used with the ICM7212M and ICM7235M.

The ICM7211, ICM7212 and ICM7235 display drivers are directly related to a family of counter/display drivers, the ICM7224, ICM7225, and ICM7236. These devices are $4^1/_2$-digit counters that directly drive LCD, LED or VF displays. They handle counting rates as high as 25MHz, display results up to 19999, and are easily cascadable to form higher resolution counters. Evaluation kits for these counters and display drivers, and the ICL7135 A/D converter, are available from Intersil.

Multiplexed LED Displays

LEDs can be multiplexed quite easily, and the ICM7218 will run 8 digits of 7 segments plus decimal point. The advantage of multiplexing is immediately apparent, as most versions of this device require only 28 pins, compared to 40 for the devices just covered, and they drive twice as many digits. Versions are available to operate common cathode and common anode type displays. A further division is made between devices where the basic access mode is serial, i.e., each digit location must be loaded in sequence, and those where digit locations are individually addressable. The serial access devices have latches to control certain operating modes, whereas the random access parts select these via full-time control pins. These modes include a "shutdown" operation where the digit and segment drivers are turned off, and the multiplex scan oscillator is halted. Data can continue to be loaded, but the power drain is typically only 10μA. Other operating modes control the data decoding function. The 8 data input lines can be used to directly control the segment and decimal point outputs, without decoding at all (the decimal point input is inverted). Alternatively, the lowest 4 data bits can be decoded according to either of the hexadecimal and "Code B" fonts shown in Table 1. The device provides interdigit blanking for about 10μs between digit drive times to avoid ghosting. The peak drive current for the common anode device is about 40mA per segment, averaging to 5mA with a 12.2% duty cycle. The common cathode drivers offer about half the current, suitable for the smaller displays of this type.

A 16-digit microprocessor display application is shown in Figure 8 using two ICM7218C devices connected to the data and address lines of an 8048 microcomputer. Note that the individual 7-segment displays are interleaved to simplify the addressing of the two driver chips. The 3 digit address lines of each ICM7218 are tied to the same 3 address lines of the 8048. When data appears on the data output lines of the 8048 and the write command is given, the display drivers will be addressed simultaneously and the 2 digits addressed by DA_0, DA_1, and DA_2 will be written simultaneously. The decimal point inputs come from the 8048 address lines. The code selected by pin 9 of the ICM7218 is hexadecimal.

Independent addressing and the no-decode mode of the ICM7218A, B, and E allow them to be used in non-numeric applications. Since each LED segment is independently addressable by way of 8 data input lines and 8 segments per digit (7 + decimal point), it is possible to use them as LED system status panel drivers or as 64-segment bar graph drivers. Two LED system status panel examples are shown in Figure 9, one with 32 channels of red and green LEDs, and one with 21 channels of red, yellow, and green LEDs. Each of these status panels can be driven by one ICM7218 display driver with individual LEDs arranged in groups of 8 for each of the 8 digit outputs.
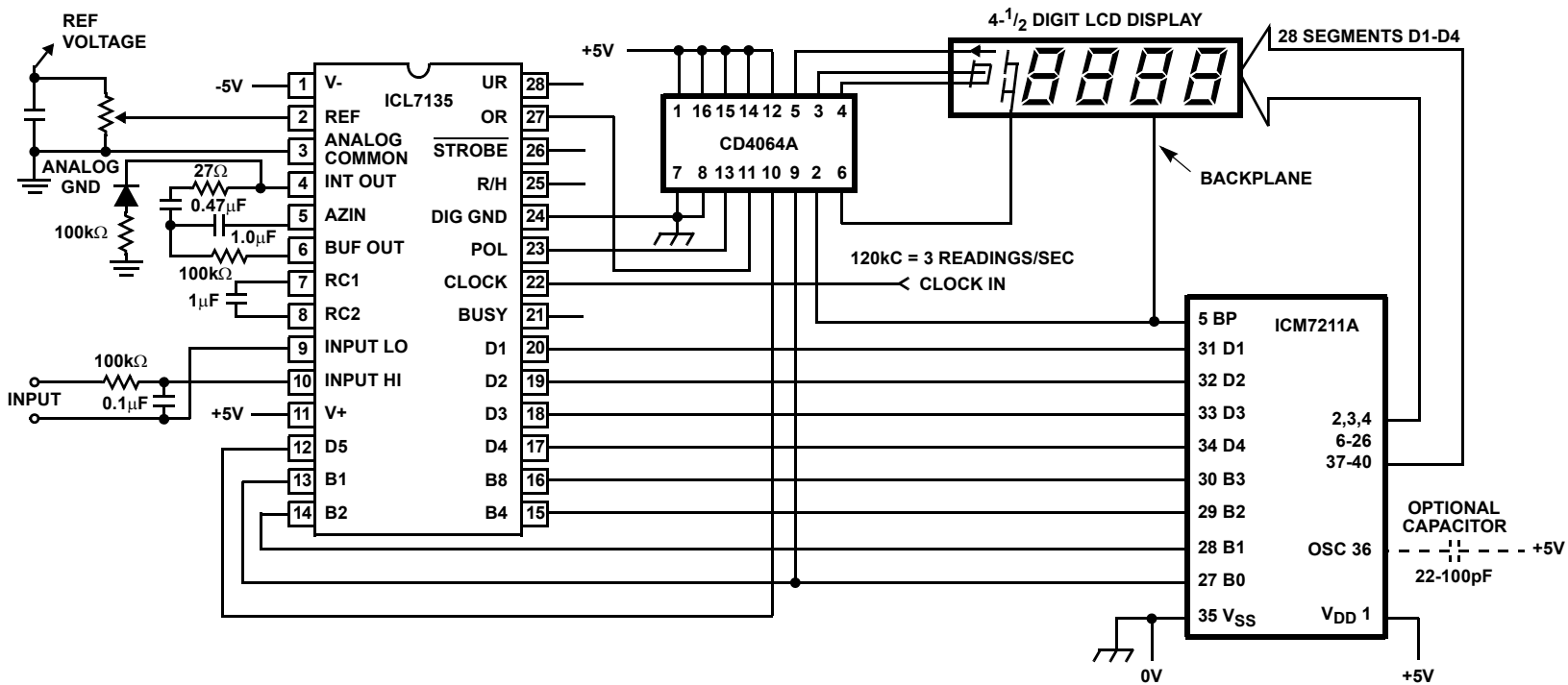
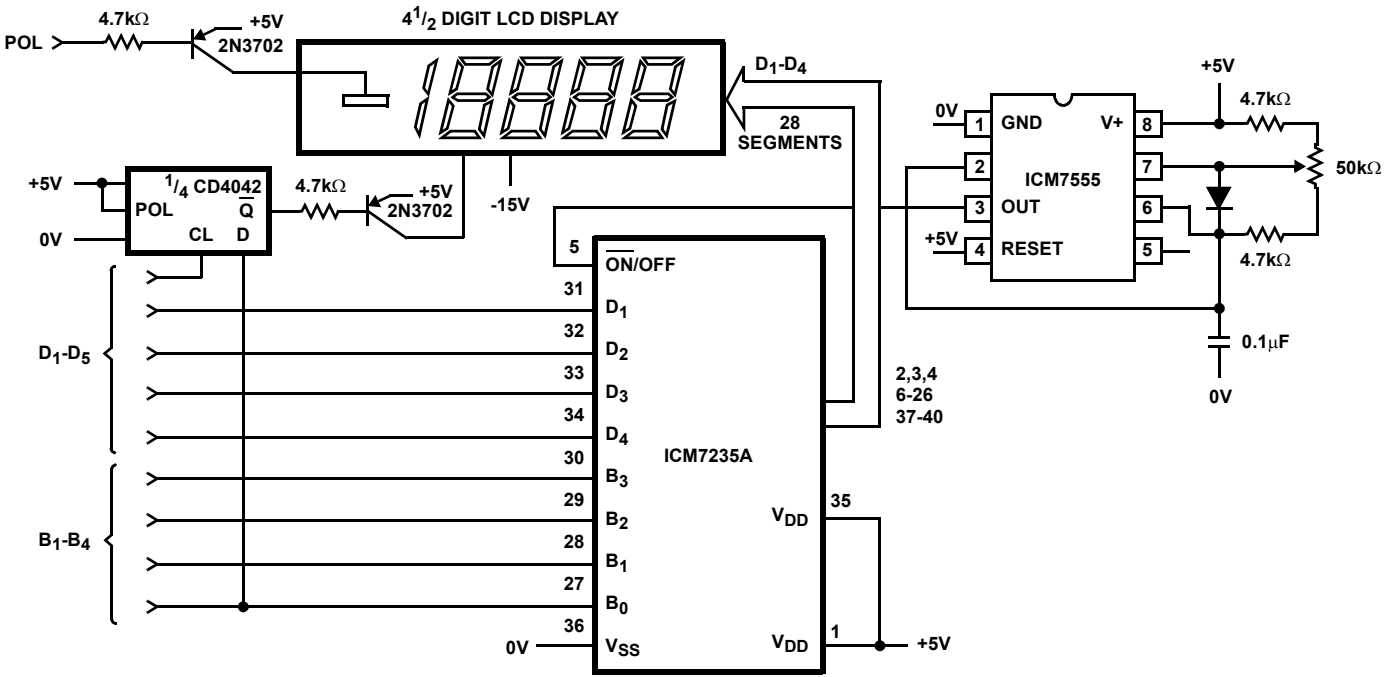**FIGURE 5. 4-1/2 DIGIT A/D CONVERTER WITH LCD DISPLAY**
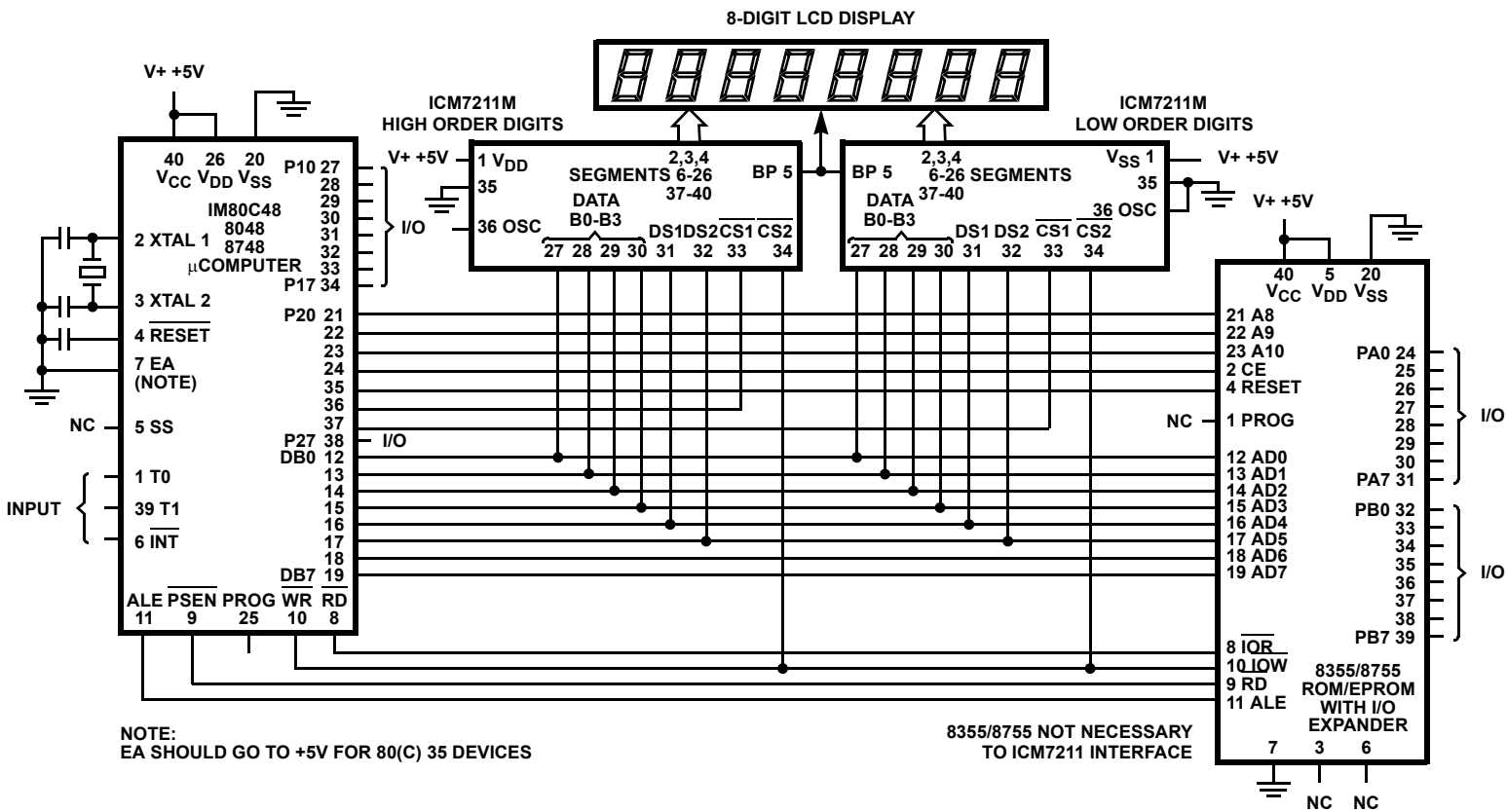
FIGURE 6. VACUUM FLORESCENT DISPLAY DRIVER

8-DIGIT LCD DISPLAY

FIGURE 7. 8-DIGIT LCD MICROCOMPUTER DISPLAY

NOTE:
EA SHOULD GO TO +5V FOR 80(C) 35 DEVICES

8355/8755 NOT NECESSARY
TO ICM7211 INTERFACE

Figure 10 shows a functional diagram of an ICM7218E used in a 6-bit binary to 64-segment bar graph application. The write control block generates the write command and address of the group of 8 segments to be written. The address is compared with the 3 MSBs of the input binary value. If the address to be written is less than the 3 MSBs, then the data is to be all "ones", turning on those 8 segments corresponding to the 3 MSBs. If the address is greater than the 3 MSBs, the data is to be all "zeros". When the address is equal to the 3 MSBs, the data generator uses the 3 LSBs of the input word to determine the point at which the bar graph changes from on to off. The data is found by: data value = $(2n) - 1$ where n is the 3-bit LSB value (0 to 8).

Note that the data sent to the decimal point input (pin 8) needs to be inverted.

Alphanumeric LED display systems have recently been simplified in the same way that the numeric-only LED display system has been simplified by the ICM7218 family (Figures 1 and 2). A pair of integrated circuits dedicated to 14- and 16-segment alphanumeric LED displays have been developed - the ICM7243A and B. These devices accept a 6-bit parallel ASCII code, decode it, and drive the appropriate segments of an 8-character common cathode display. The mask programmable character sets and corresponding ASCII codes are shown in Figures 11 and 12 for the 14-and 16-segment versions.

The ICM 7243 has 2 input data modes. The Random Access (RA) mode allows independent addressing of characters by way of 3-digit address lines. The RA mode writes only the character addressed. The Serial Access (SA) mode writes characters from left to right on the display without having to externally address each character. Right to left writing can be done by wiring the digits in reverse order. The OSC/OFF pin on the ICM7243 provides a shutdown mode which, when grounded, will put the display driver in a low-power mode, blanking the displays while the memory reaction is kept active. The DISPLAY FULL and SERIAL ENABLE lines combine to make cascading display drivers easy. An example of a 24-character LED display is shown in Figure 13. The MODE lines are all tied high to set up serial input, and DISPLAY FULL is connected to SEN of the next device to enable cascading. When CHIP SELECT is high, the WRITE line is active-low. If however, active-high is desired, WRITE can be tied low and CHIP SELECT used as an active-high write line. The characters will be written from left to right as new ASCII data is presented to the 6-bit input bus and the WRITE command is given.

Figure 14 shows the use of the OSC/OFF pin to get the shutdown mode. In this example two ICM7243s are dedicated to the same 8 characters of the LED display. The drivers are enabled alternately, performing a message select function. When the OSC/OFF pin is brought low by the open-collector inverter, all outputs of that driver are turned off, freeing its group of 8 LED characters to be driven by the other ICM7243. The display driver is turned on by allowing the OSC/OFF pin to float.

The average segment current of the ICM7243 is 3mA maximum (24mA/8 digits). This is quite enough current to give good contrast to the 0.375 or 0.4 inch high displays. If larger displays are to be driven it is an easy task to add a simple transistor current boost circuit to each character and segment output. The current boost circuit shown in Figure 15 will provide an average segment current of about 12mA. This current should be sufficient to drive larger alphanumeric LED displays.

Multiplexed Liquid Crystal Displays

The benefits of multiplexing have been slow in coming to LCD systems, outside of a few consumer items. Much of the reason lies with the display. A reverse biased LED (or VF device) will not display anything, so part-time forward bias control is enough to control the overall result. But LCDs require an AC drive, and continuously look at the voltage between backplane and segment. Thus, multiplexing LCDs require waveforms that rely on a threshold in the RMS voltage-vs contrast characteristics. The result is that until recently no multiplexed LCD displays were commercially available (off-the-shelf), and naturally it is hard to justify building display drivers for unavailable displays! Nevertheless, Intersil had introduced the ICM7231/32/33/34 family of Triplex Multiplexed LCD drivers and several matching LCD displays have become available. Figure 16 shows a block diagram of the ICM7233 display driver for 4 characters of 18 segments.

The 6 data input lines are decoded into 18 segment lines according to the font shown in Table 2. These are then latched in the character location selected by the two address lines at the rising edge of one of the Chip Select inputs. The segments are arranged on 6 segment lines against 3 common (backplane) lines as shown in Figure 17. The resistive divider sets up a total of 4 voltage levels and the COMmon and SEGment lines are switched between these levels as shown in Figure 18. The resulting voltages between one segment in the display and its common backplane are shown in Figure 19. The ratio of RMS voltages for ON and OFF conditions of the segment is 1.92:1 as shown. The relationship between contrast and applied voltage for a typical multiplexed LCD display is shown in Figure 20, and indicates that the viewing angle for adequate contrast at this level is satisfactory. Figure 21 shows the variation with temperature of the voltage margins (expressed as peak voltage) above and below which the display will begin to malfunction.

The ICM7231 uses 4 of the input data lines for binary display data, and 2 more for annunciator inputs. The segment latches are divided into 8 groups (digits) of 9 (7 segments plus 2 annunciators) with 1 extra address input provided for selection. Several different versions offer hexadecimal or Code B fonts (Table 1) and different annunciator connections (see Figure 22 for patterns).
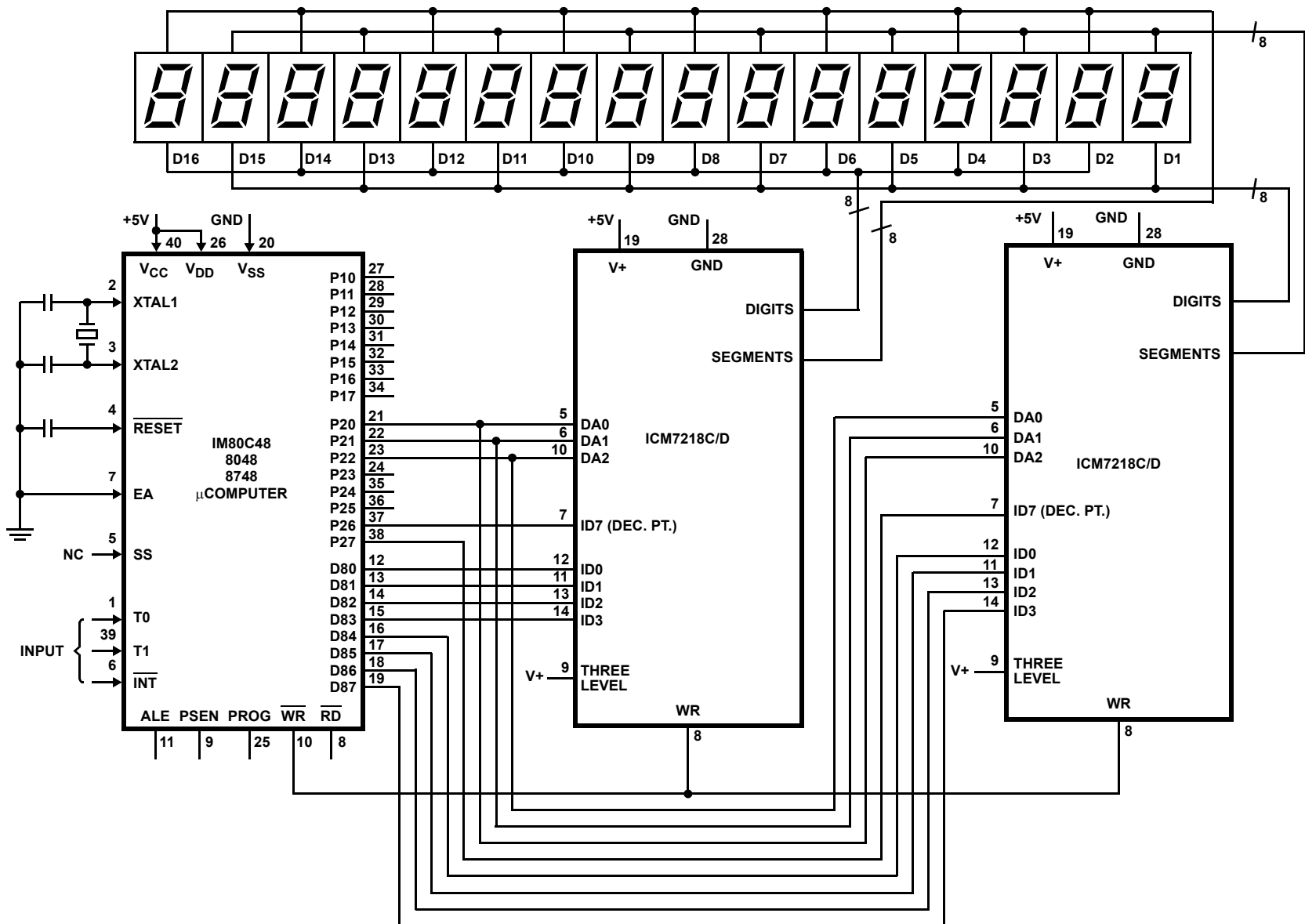
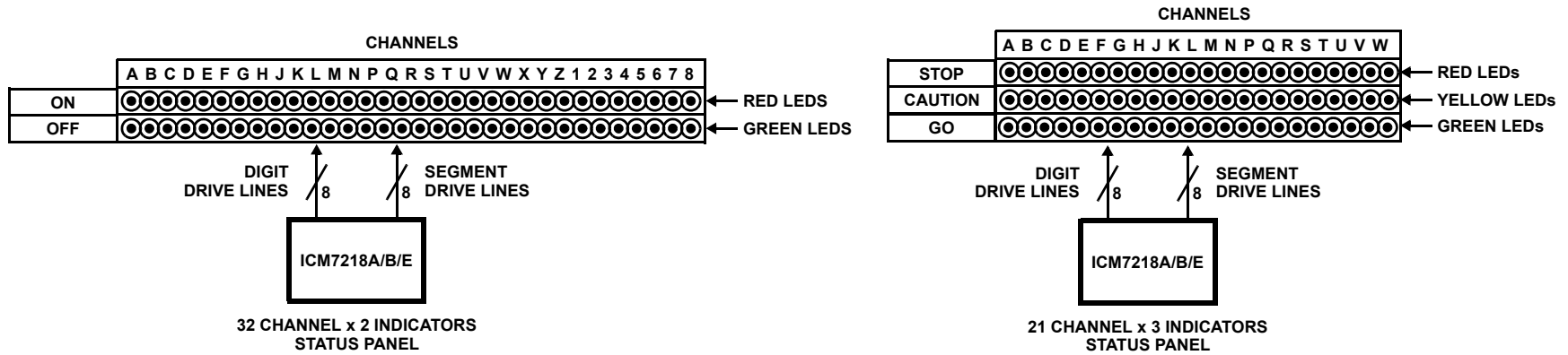**FIGURE 8. 16-DIGIT LED MICROCOMPUTER DISPLAY**

Display Driver Family Combines Convenience of Use with Microprocessor Interfaceability

CHANNELS

A B C D E F G H J K L M N P Q R S T U V W X Y Z 1 2 3 4 5 6 7 8

| ON | | ← RED LEDS |
| OFF | | ← GREEN LEDS |

DIGIT DRIVE LINES /8

SEGMENT DRIVE LINES /8

ICM7218A/B/E

32 CHANNEL x 2 INDICATORS STATUS PANEL

CHANNELS

A B C D E F G H J K L M N P Q R S T U V W

STOP		← RED LEDs
CAUTION		← YELLOW LEDs
GO		← GREEN LEDs

DIGIT DRIVE LINES /8

SEGMENT DRIVE LINES /8

ICM7218A/B/E

21 CHANNEL x 3 INDICATORS STATUS PANEL

FIGURE 9. STATUS PANEL EXAMPLES FOR ICM7218

BINARY DATA (LSBs) 3/ → DATA GENERATOR → 8/ → DP

7/ → DATA

"<" "=" ">"

BINARY DATA (MSBs) 3/ → 3-BIT COMPARATOR

ICM7218A/B/E

8/ SEGMENT

64-SEGMENT BAR GRAPH

3/ → ADDRESS

$\overline{WR}$

8/ DIGIT

3/

ADDRESS GENERATOR AND WRITE CONTROL
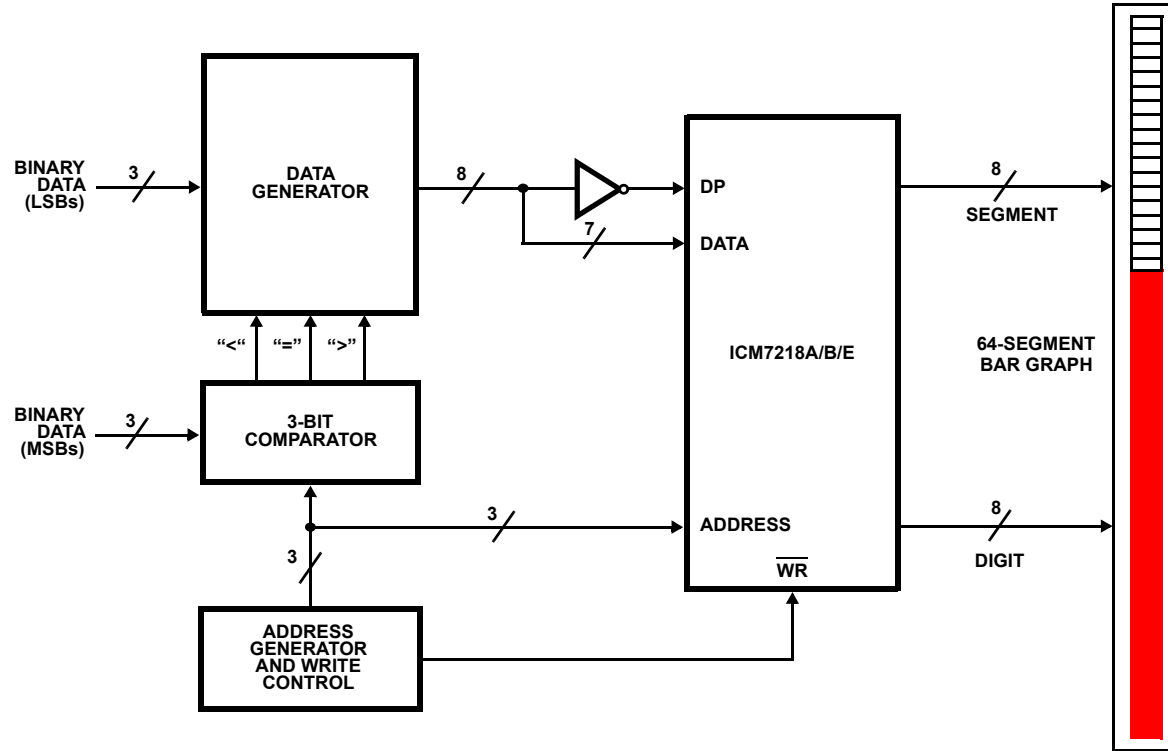
FIGURE 10. 6-BIT BINARY TO BAR GRAPH APPLICATION

D₅, D₄		a1 a2 f h i j b g1 g2 e m l k c d2 d1 · DP
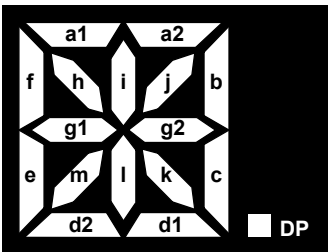
		@ A B C D E F G H I J K L M N O
0	0	
0	1	P Q R S T U V W X Y Z [\ ] ↗ _
1	0	! " £ $ % & ' ( ) ✳ + , - . /
1	1	0 1 2 3 4 5 6 7 8 9 . ' ∠ = ⌐ ?

	D₃	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
	D₂	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
	D₁	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
	D₀	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

FIGURE 11. ICM7243A 16-SEGMENT CHARACTER FONT WITH DECIMAL POINT

			0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
		D_3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
		D_2	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
		D_1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
		D_0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

NOTE: Segments a and d appear as 2 segments each, but both halves are driven together.

FIGURE 12. ICM7243B 14-SEGMENT CHARACTER FONT WITH DECIMAL POINT
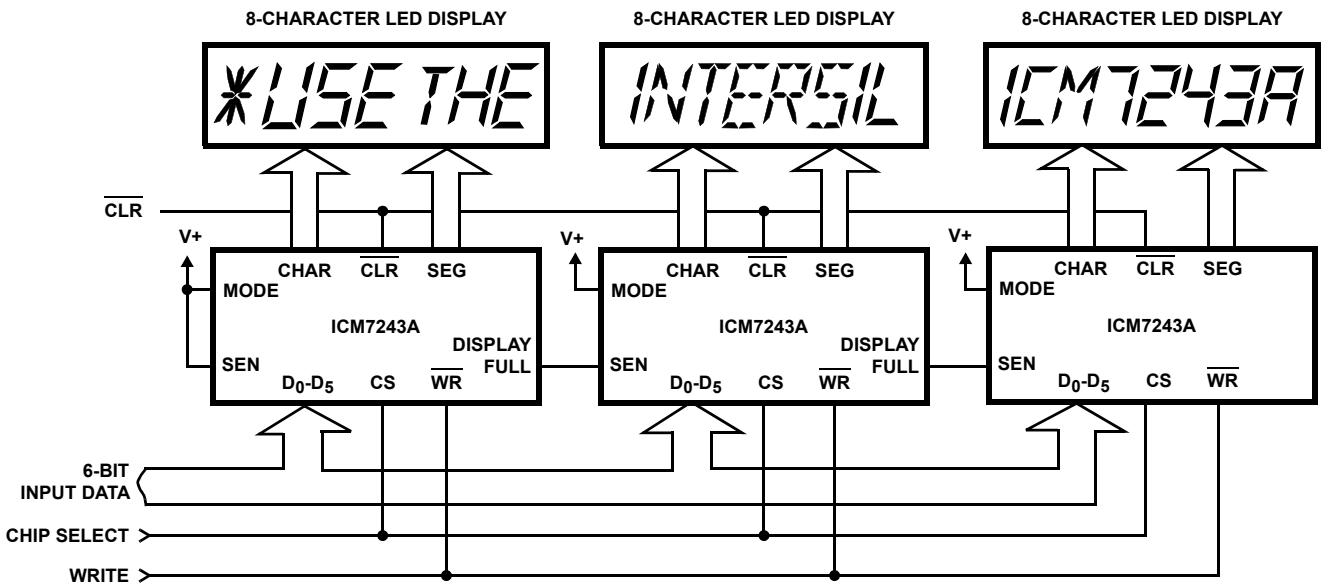
FIGURE 13. 24-CHARACTER LED MICROCOMPUTER DISPLAY
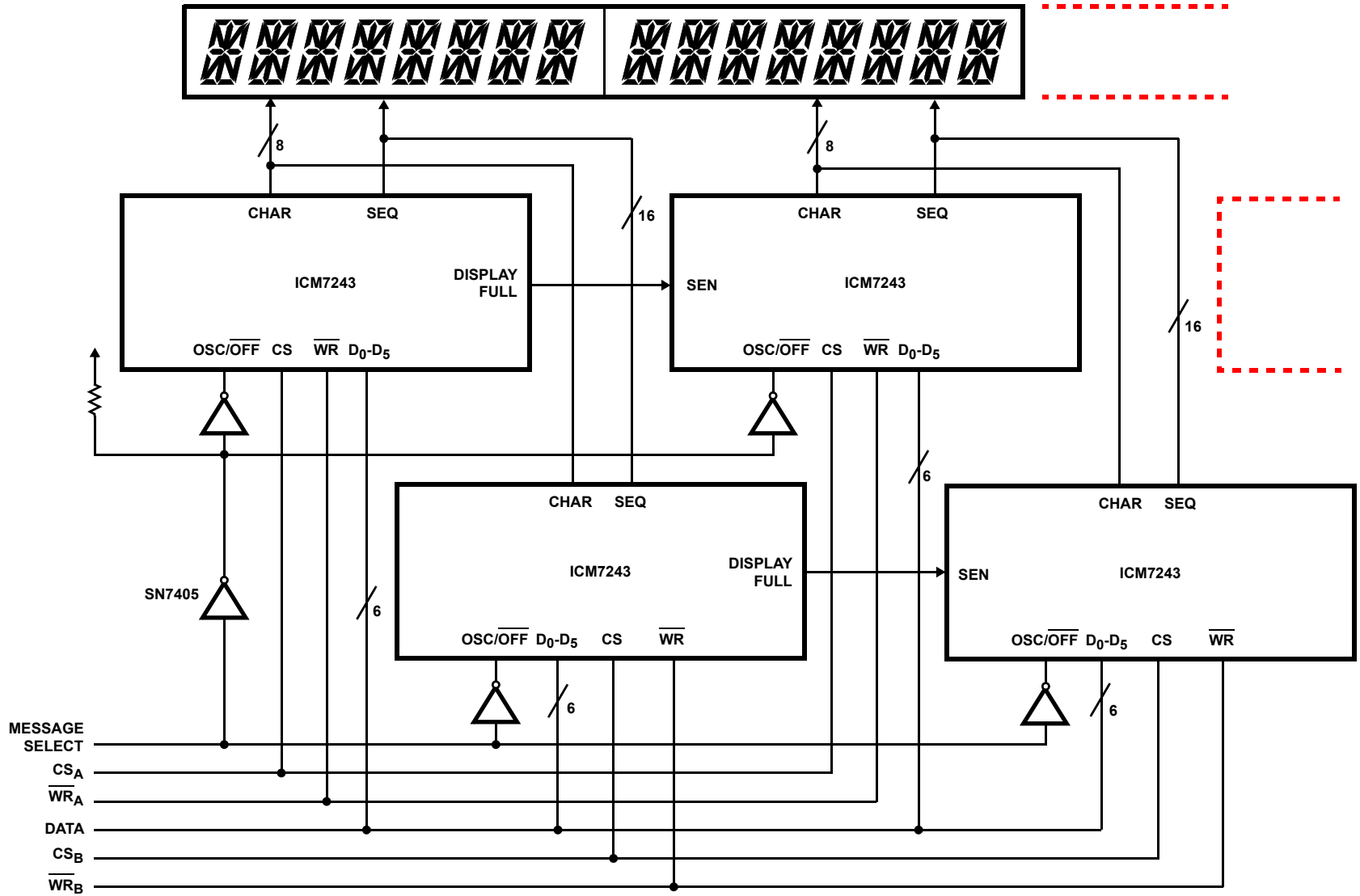
FIGURE 14. ICM7243 MESSAGE SELECT APPLICATION
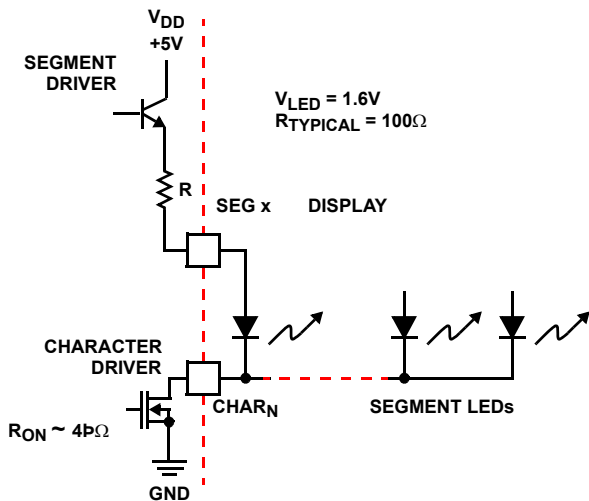
FIGURE 15A. STANDARD DISPLAY CONNECTION
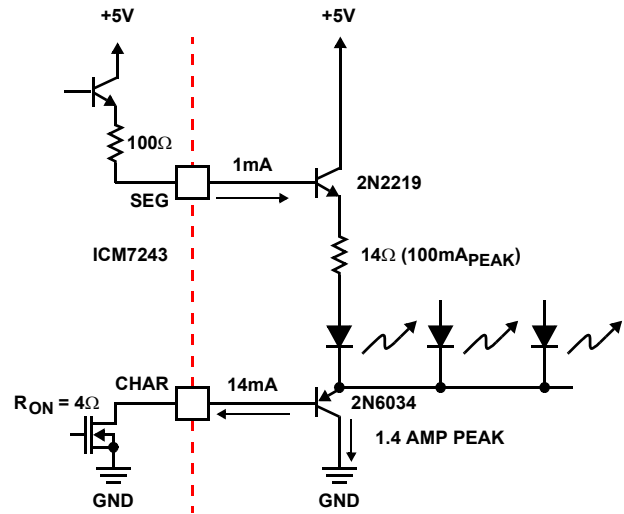
FIGURE 15B. LED CURRENT BOOST CONNECTION

FIGURE 15. DISPLAY CURRENT BOOST CIRCUIT FOR ICM7243

The serial input versions, the ICM7232 and ICM7234, exchange the 6 data input lines for 6 more SEGment lines, allowing 2 digits or one character extra per driver. The Address and Chip Select Lines are replaced by 4 serial input control lines (Figure 23) which clock data and address information into a shift register before writing it into the display. A DATA ACCEPTED flag output indicates when enough data has been entered into the shift register, and enables the writing operation. WRite pulses also reset the shift register and DATA ACCEPTED flag. The two annunciator locations need not be filled, and clocking more data into the shift register than it can accept causes an automatic reset. This minimizes the chance of displaying incorrect information.

The serial input format on the ICM7234 is similar (Figure 24) except that all bits need to be loaded into the shift register to determine the character code and location. Data to be written into nonexistent addresses is ignored.

The initial setup of the optimum display voltage, and its variation with temperature, shown in Figure 21, is accommodated in the ICM7231/32/33/34 devices by separating the display driving voltage from the logic voltage, and also allowing the input signals to exceed the logic supply in one direction. The display voltage can be controlled by the use of the ICL7663, as shown in Figure 25.

The device pinouts are arranged to simplify the board layout of display systems. The basic layout for the ICM7231 and a corresponding display, for example, is shown in Figure 26, and the others are similar.

The convenient interface with microprocessors is indicated in Figure 27. Here the 8-bit bus of an MCS-48 microcomputer is used to provide the 6 data bits and the 2 address bits for writing to a series of 4-character drivers, the ICM7233. Port lines select specific drivers via one of the $\overline{\text{CHIP}}$ $\overline{\text{SELECT}}$ lines, while the other provides $\overline{\text{WR}}$ cycle timing. A similar

arrangement can be used with any microprocessor that provides a $\overline{\text{WR}}$ line, such as the MCS-80/85. A slightly more complex interface to an MC680X processor is shown in Figure 28. Here, address lines are used for character and chip selection, enabled by a port line from another peripheral chip. Note that in both these circuits, and any other multiple chip systems of this kind, the 3 common lines must be separated for each group of digits or characters. Several displays organized in this manner are now available from some vendors (notable Epson), and more are expected soon.

An example of the serial interface connection can be seen in Figure 29 where a COPS420C microcomputer has been fitted with a 10-character alphanumeric LCD display. The display and drivers can easily be located at some remote point in the system and communicate with the microcomputer via the 4 data lines, serial data, serial clock, WRITE 1, and WRITE 2.

The microcomputer controls which character is being written by sending the appropriate write pulse and by sending the digit address bits. The last 3 bits in the string of 9 sent to the ICM7234s are the digit address bits. Since the digit addressing is sent with each data word, the display may be written in random access mode.

Summary

The display drivers mentioned here are examples of how CMOS technology is being used to simplify the design of numeric and alphanumeric display systems. The method of driving (direct, multiplex, triplex) is not usually as important to a system designer as the questions regarding the type of display (LCD, LED, Vacuum Fluorescent, Gas Discharge), the size of display, and the number of digits or characters. The actual construction of display systems is easier now that there is a wide selection of decoder/drivers from which to choose.
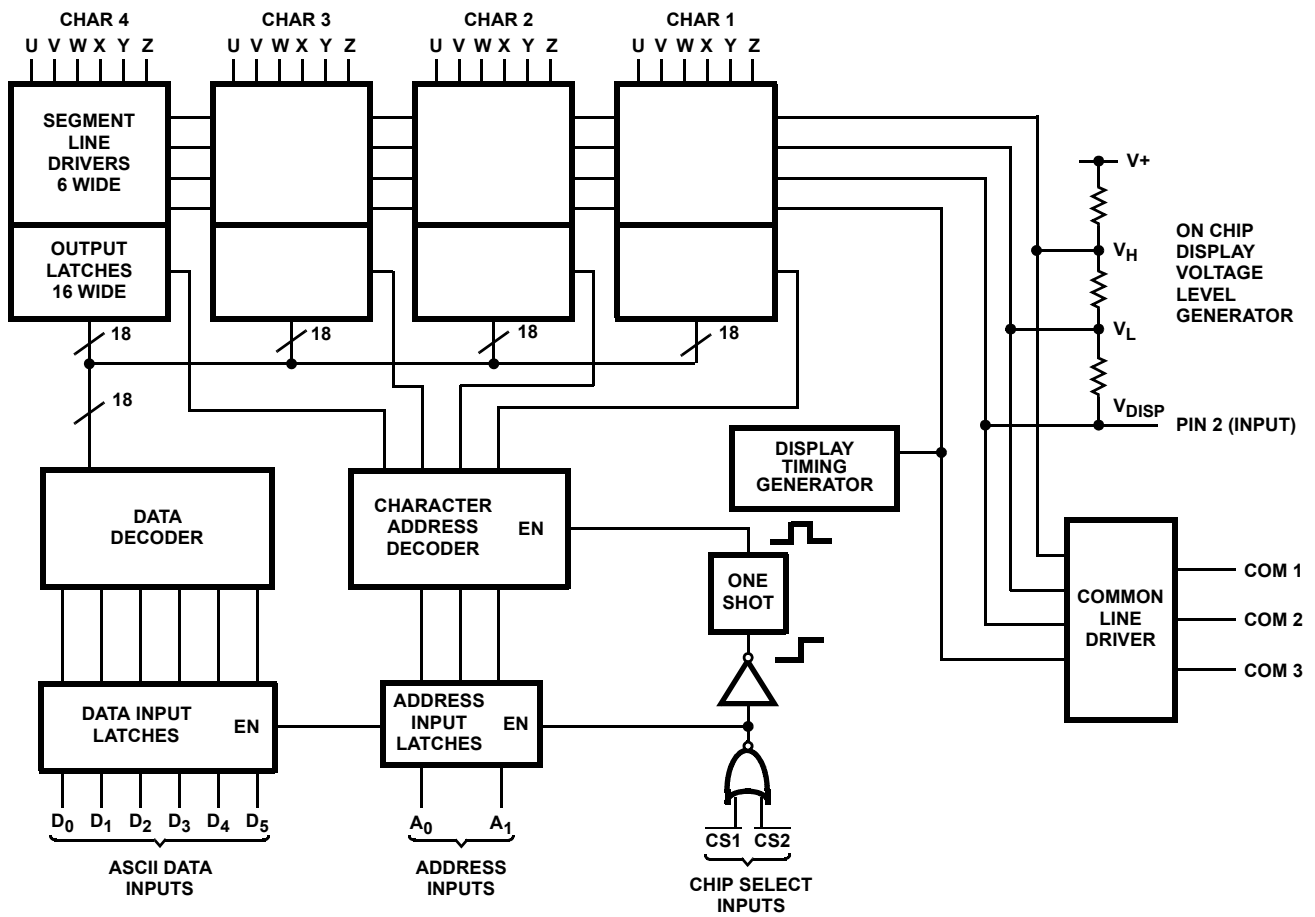
FIGURE 16. ICM7233 FUNCTIONAL DIAGRAM

TABLE 2. 6-BIT ASCII 18-SEGMENT FONT (ICM7233, ICM7234)

CODE INPUT				DISPLAY OUTPUT D_5, D_4			
D_3	D_2	D_1	D_0	0, 0	0, 1	1, 0	1, 1
0	0	0	0	@	P		0
0	0	0	1	A	Q	!	1
0	0	1	0	B	R	"	2
0	0	1	1	C	S	#	3
0	1	0	0	D	T	$	4
0	1	0	1	E	U	%	5
0	1	1	0	F	V	&	6
0	1	1	1	G	W	'	7

TABLE 2. 6-BIT ASCII 18-SEGMENT FONT (ICM7233, ICM7234)   (Continued)

CODE INPUT				DISPLAY OUTPUT D_5, D_4			
D_3	D_2	D_1	D_0	0, 0	0, 1	1, 0	1, 1
1	0	0	0	H	X	(	8
1	0	0	1	I	Y	)	9
1	0	1	0	J	Z	*	:
1	0	1	1	K	[	+	;
1	1	0	0	L	\	,	<
1	1	0	1	M	]	-	=
1	1	1	0	N	^	.	>
1	1	1	1	O	←	/	?

FIGURE 17A. SEGMENT LINE CONNECTIONS
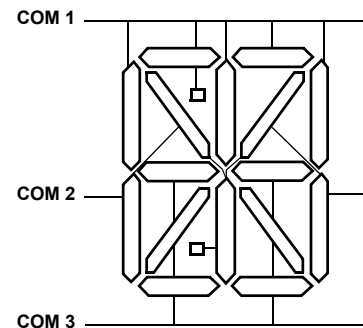
FIGURE 17B. COMMON LINE CONNECTIONS

FIGURE 17. ICM7233 AND ICM7234 SEGMENT PATTERN 18-SEGMENT ALPHANUMERIC
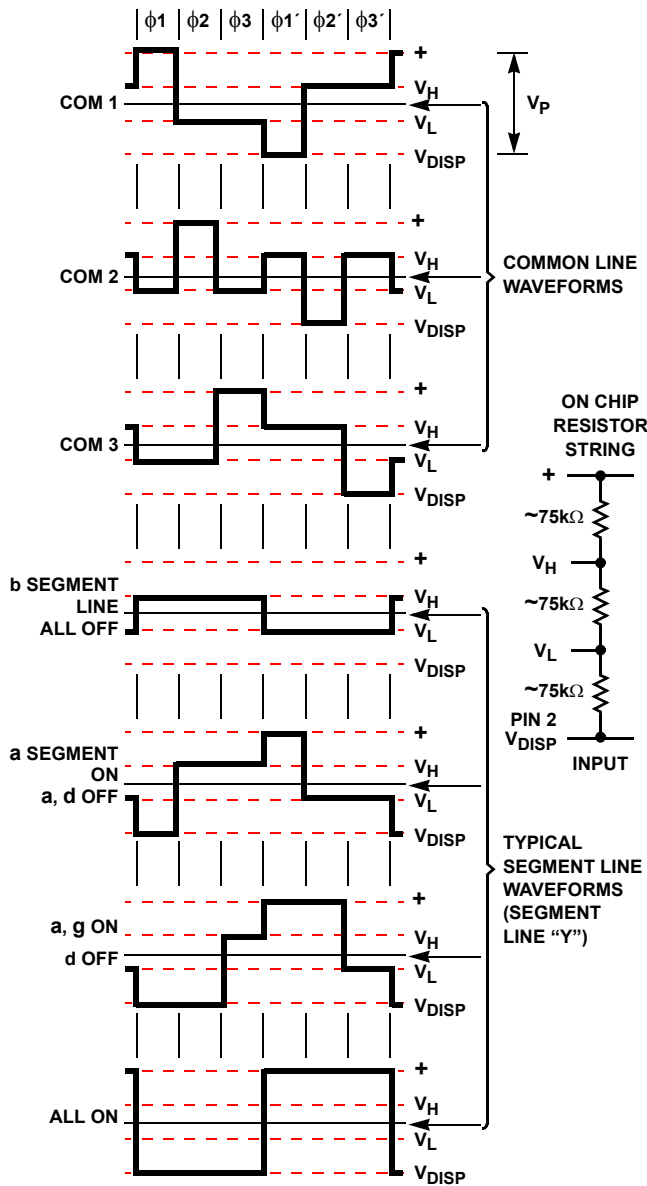
NOTES:

1. $\phi1$, $\phi2$, $\phi3$, - Common High with Respect to Segment.

2. $\phi1'$, $\phi2'$, $\phi3'$, - BP Low with Respect to Segment.

3. COM 1 Active during $\phi1$, and $\phi1'$.

4. COM 2 Active during $\phi2$, and $\phi2'$.

5. COM 3 Active during $\phi3$, and $\phi3'$.

FIGURE 18. DISPLAY VOLTAGE WAVEFORMS

$$VP = (V+) - V_{DISP}$$

$$V_{RMS} = \frac{VP}{3} = V_{RMS}OFF$$

$$V_{RMS} = \frac{\sqrt{11}}{\sqrt{3}} \times \frac{VP}{3} = V_{RMS}ON$$
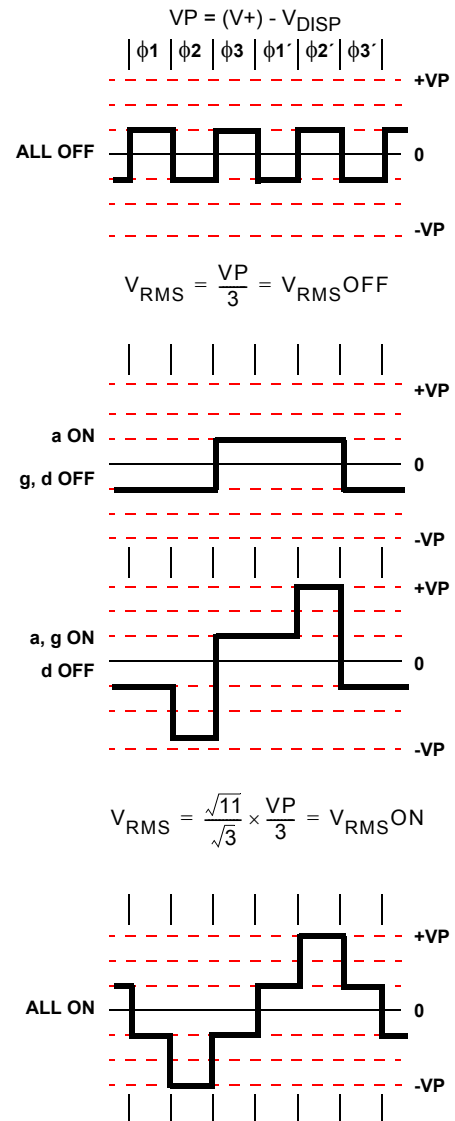
$$\text{Voltage Contrast Ratio} = \frac{V_{RMS}ON}{V_{RMS}OFF} = \frac{\sqrt{11}}{\sqrt{3}} = 1.92$$

NOTES:

1. $\phi1$, $\phi2$, $\phi3$, - Common High with Respect to Segment.

2. $\phi1'$, $\phi2'$, $\phi3'$, - Common Low with Respect to Segment.

3. COM 1 Active during $\phi1$, and $\phi1'$.

4. COM 2 Active during $\phi2$, and $\phi2'$.

5. COM 3 Active during $\phi3$, and $\phi3'$.

FIGURE 19. VOLTAGE WAVEFORMS ON SEGMENT
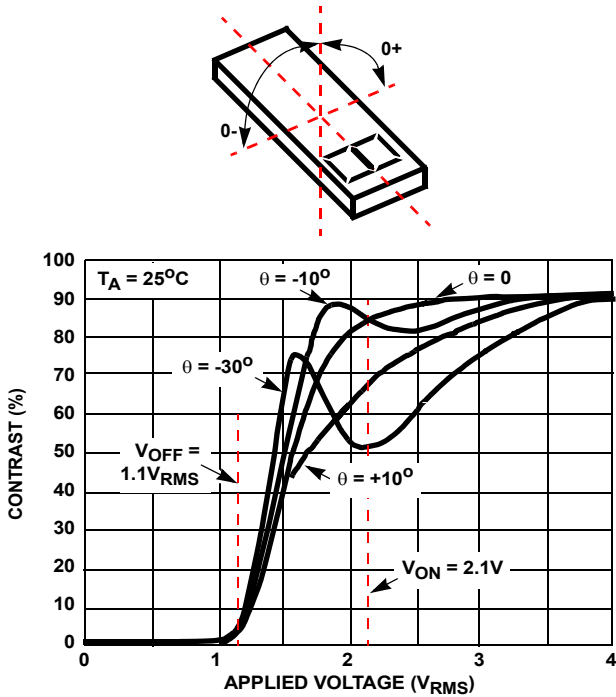
FIGURE 20. CONTRAST vs APPLIED RMS VOLTAGE
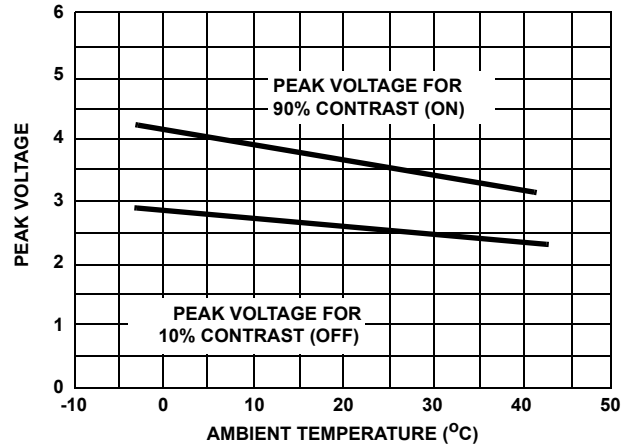
FIGURE 21. TEMPERATURE DEPENDENCE OF LC THRESHOLD

FIGURE 22. ICM7231 AND ICM7232 DISPLAY PATTERNS
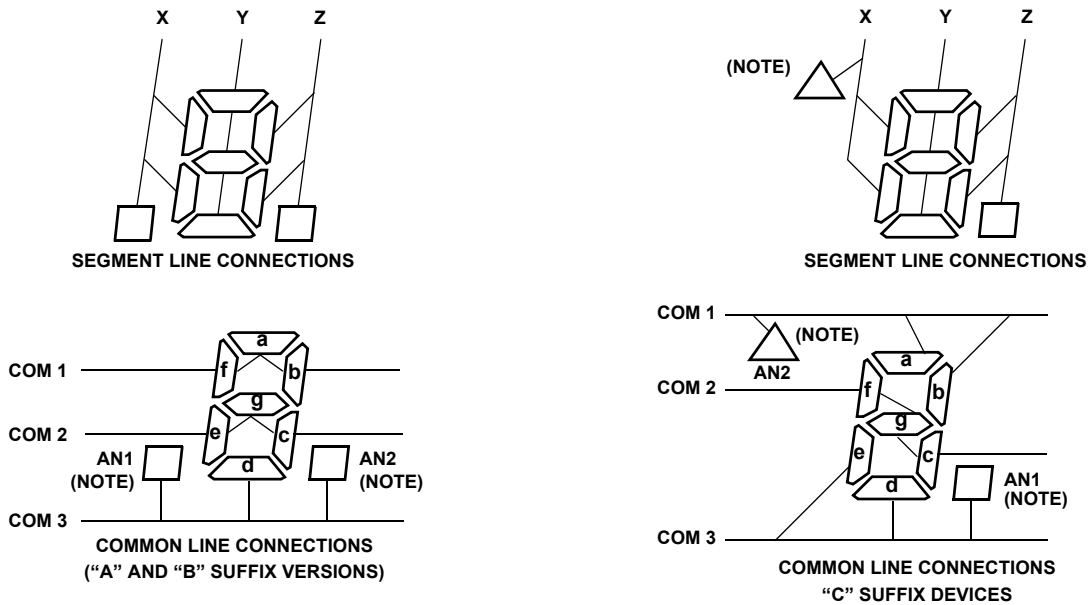
NOTE: Annunciators can be: STOP , GO , △ , ↑ -arrows that point to information printed around the display opening etc., whatever the designer display opening etc., whatever the designer chooses to incorporate in the liquid crystal display.
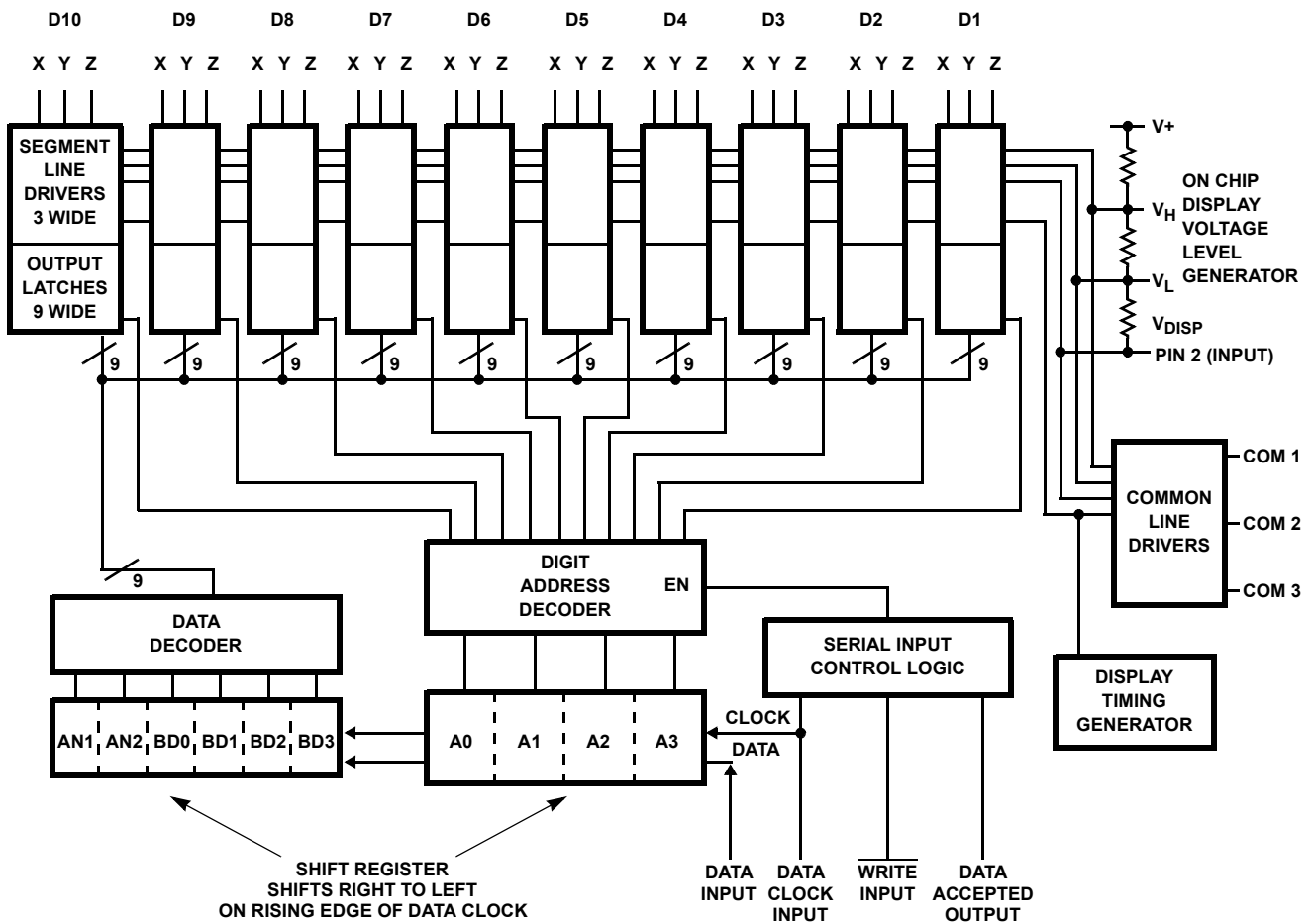
FIGURE 23. ICM7232 FUNCTIONAL DIAGRAM

Display Driver Family Combines Convenience of Use with Microprocessor Interfaceability

D$_0$ WRITE FIRST	D$_1$	D$_2$	D$_3$	D$_4$	D$_5$	A$_0$	A$_1$	A$_2$ WRITE LAST

WRITE ORDER

= DON'T CARE

DATA CLOCK INPUT

① ② ③ ⑧ ⑨

TENTH CLOCK WITH NO WRITE PULSE RESETS SR AND LOGIC

t$_{DH}$

DATA INPUT

t$_{DS}$

D0 DATA VALID   D1 DATA VALID   D2 DATA VALID   A1 DATA VALID   A2 DATA VALID

DATA ACCEPTED OUTPUT

t$_{ODI}$ t$_{ODI}$

t$_{WLL}$

t$_{WP}$

t$_{WP}$

t$_{CWS}$ t$_{ODH}$

WRITE INPUT

RESETS SHIFT REGISTER AND CONTROL LOGIC IF DATA ACCEPTED IS HIGH

DECODES AND STORES DATA, RESETS SHIFT REGISTER AND LOGIC WHEN DATA ACCEPTED IS LOW

FIGURE 24. ICM7234 ONE CHARACTER INPUT TIMING DIAGRAM
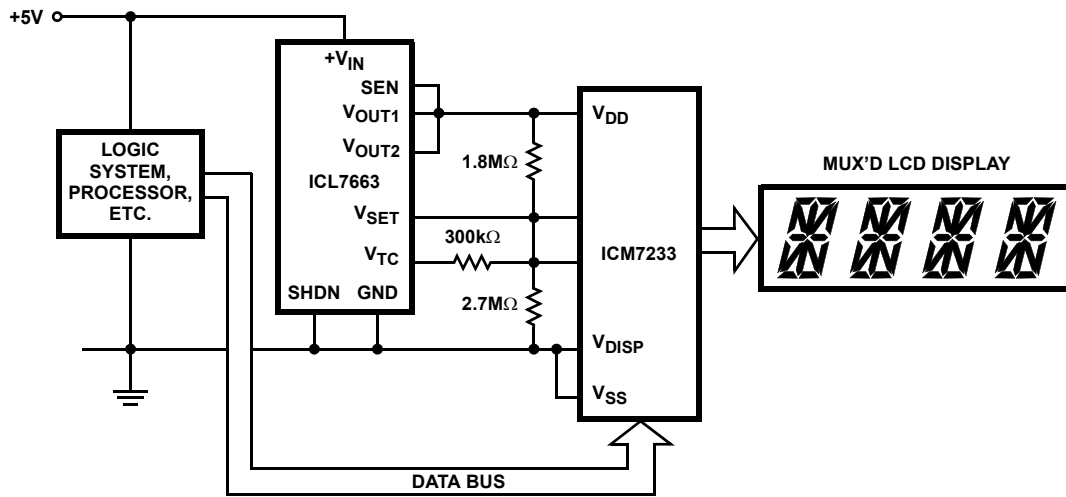
FIGURE 25. DRIVING A MULTIPLEXED LCD DISPLAY
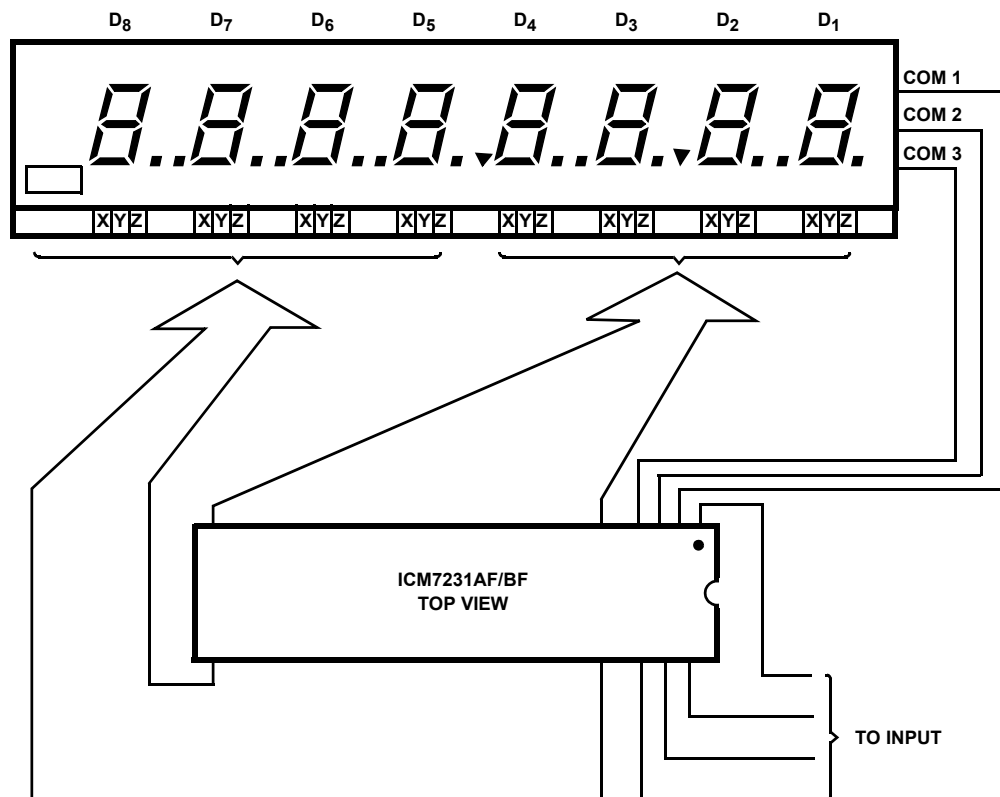
FIGURE 26. PIN ORIENTATION AND DISPLAY CONNECTIONS

RENESAS
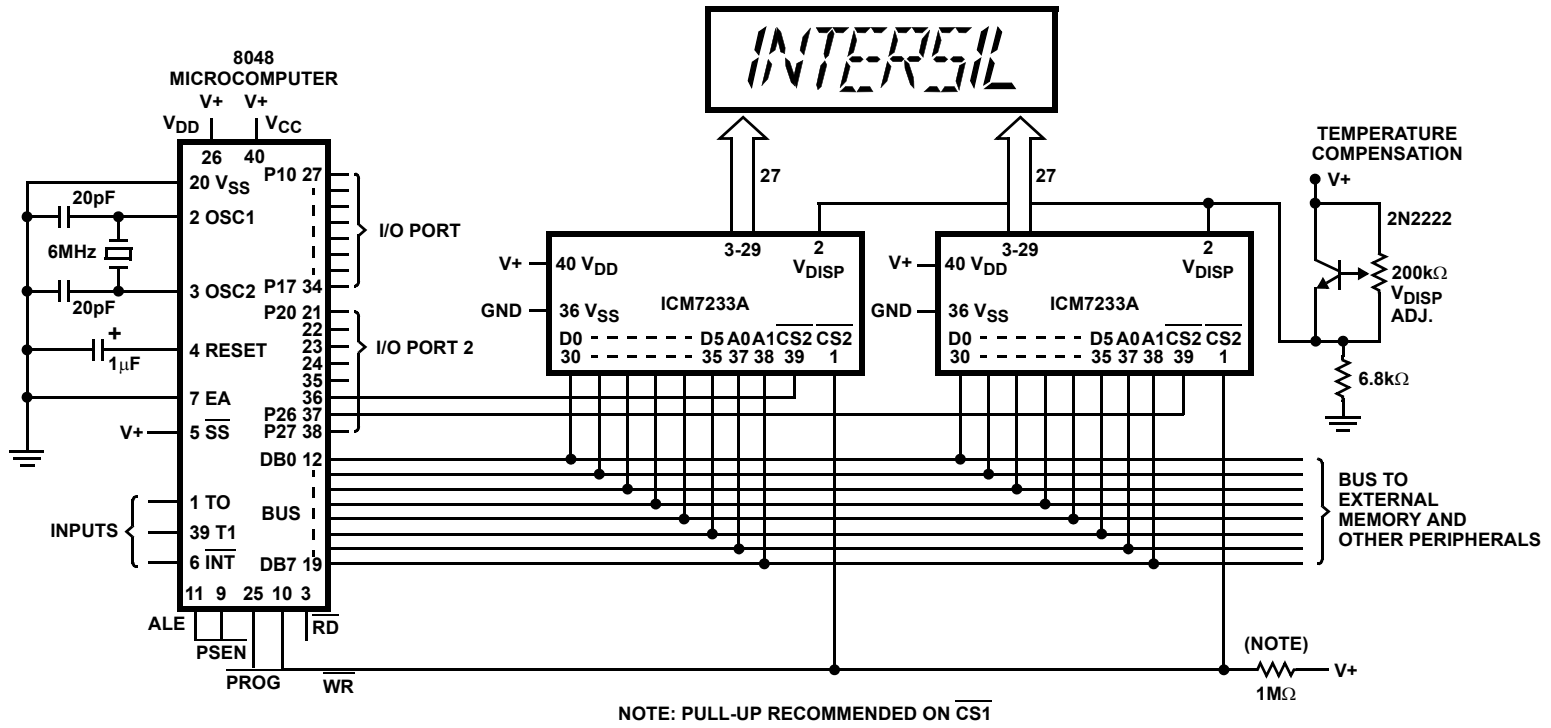
FIGURE 27. 8048/IM80C40 MICROCOMPUTER WITH 8-CHARACTER 16-SEGMENT FULL ASCII TRIPLEX LIQUID CRYSTAL DISPLAY
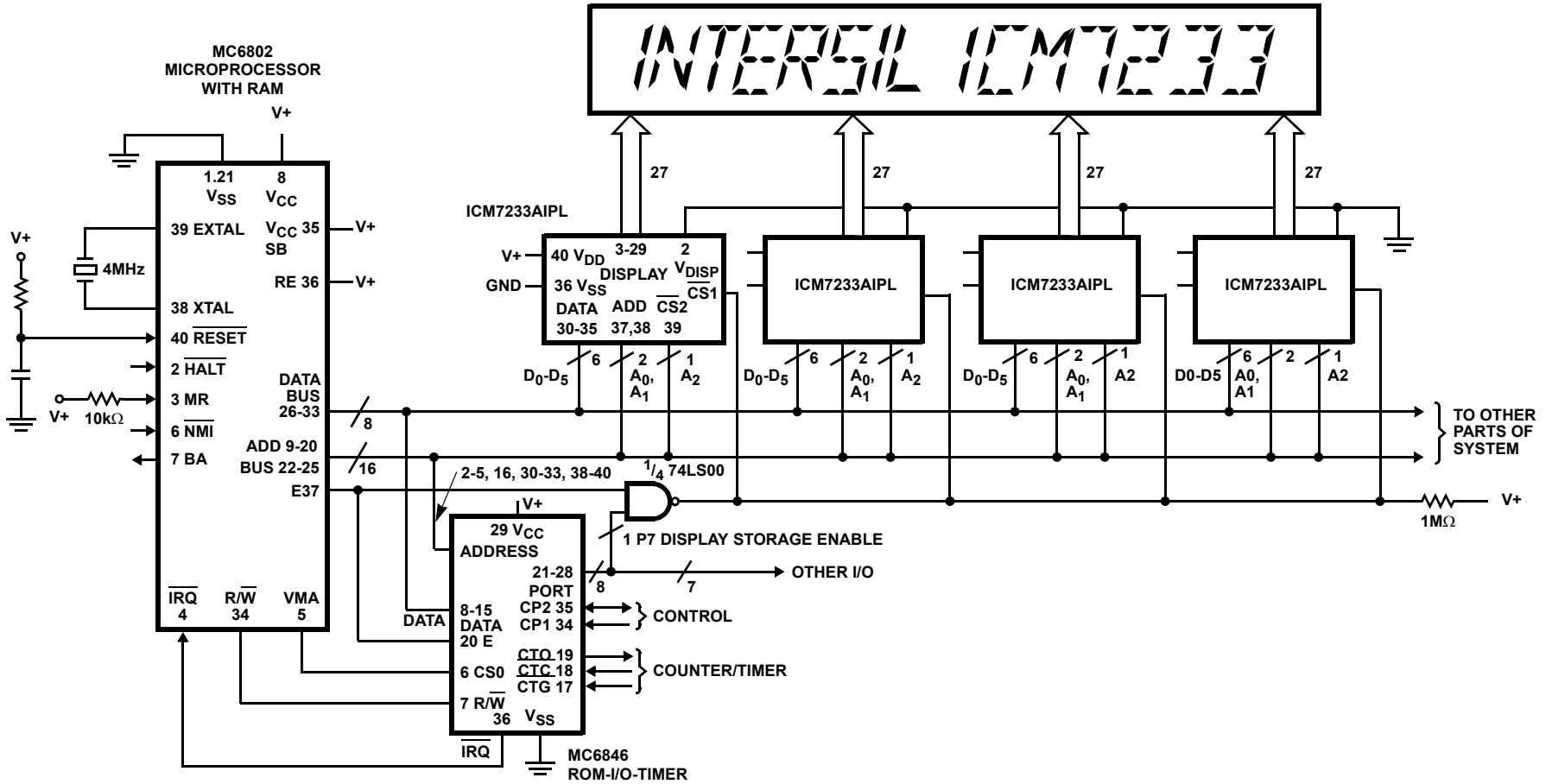
FIGURE 28. MC6502 MICROPROCESSOR WITH 16-CHARACTER 16-SEGMENT FULL ASCII LIQUID CRYSTAL DISPLAY
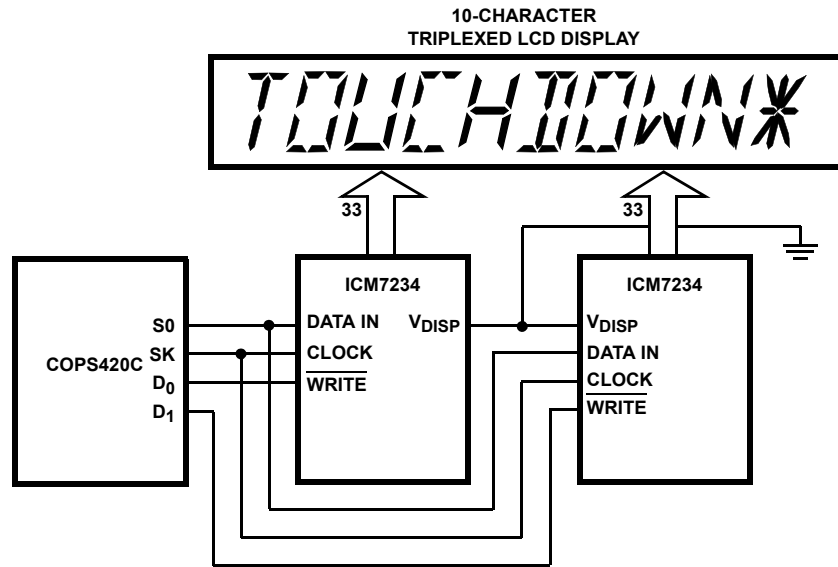
FIGURE 29. 10-CHARACTER ALPHANUMERIC TRIPLEXED LCD DISPLAY WITH SERIAL MICROCOMPUTER INTERFACE

RENESAS

Renesas Electronics Corporation

http://www.renesas.com

SALES OFFICES

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338