RCA Electronic Components

Digital Display Devices
Application Note
AN-4277

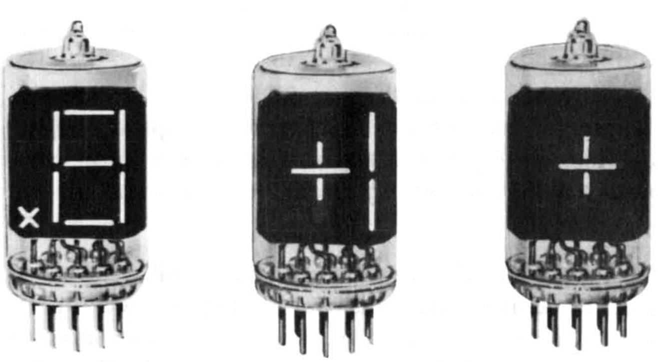
Description and Application of NUMITRON Digital Display Devices

The NUMITRON digital-display devices DR2000, DR2010, DR2020, and DR2030 are incandescent readout devices that provide sharp, high-brightness displays ideally suited for most types of digital-readout systems. These devices, which may be operated in either a dc or multiplex mode, offer the designers of digital-display systems the following major advantages:

- high-contrast clutter-free displays in virtually any desired color with controllable brightness
- low-voltage operation (4.5 volts nominal)
- wide viewing angle
- minimum center-to-center mounting distance between adjacent devices of only 0.80 inch
- use of standard low-cost sockets
- freedom from induced or radiated interference
- full compatibility with low-cost integrated-circuit decoder/drivers
- high reliability (life expectancy exceeds 100,000 hours)

BASIC FEATURES OF THE NUMITRON DEVICES

Fig. 1 shows an external view of the NUMITRON devices. Each device contains a number of incandescent single-helical coil segments in an evacuated glass envelope. The desired display is achieved by application of dc voltages to the appropriate coil-segment pin connections. During operation, the coil segments glow in a clear, brilliant fine line. If a broader stroke is desired, etched or other specially treated glass, such as Trusite,* can be placed in front of the device.



DR2000
0 through 9

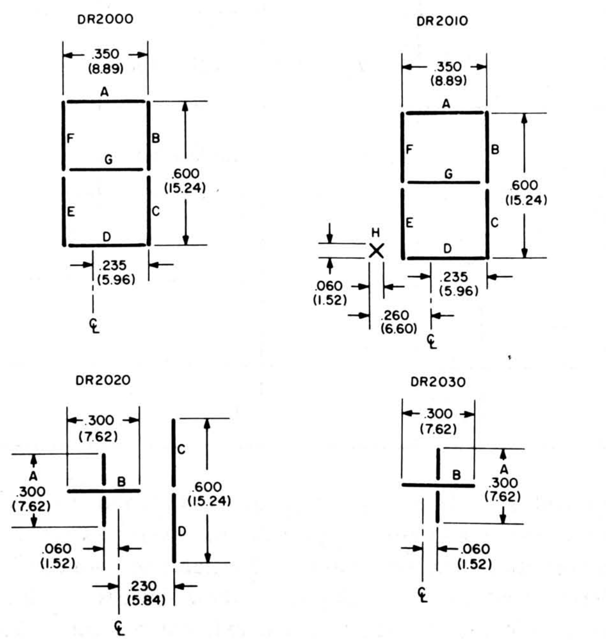
DR2010
0 through 9
with decimal point

DR2020
Plus-Minus sign
and numeral 1

DR2030
Plus-Minus sign

Fig. 1 - NUMITRON digital display devices.

Character Formation: Fig. 2 shows schematic representations and dimensions of the coil-segment arrangement for each type of NUMITRON device. (The letter designations of the coil segments are assigned for convenience of identification only.) The DR2000 can provide a readout of any of the numerals 0 through 9; the DR2010 can display any of the numerals 0 through 9 and a decimal point; the DR2020 can be used to form the numeral 1 or the numeral 1 preceded by either a plus or a minus sign; the DR2030 can provide either



Notes: **1.** Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

2. ℄ = vertical center line of device with pin No.3 toward viewer.

Fig. 2 - Coil-segment arrangements in NUMITRON devices.

a plus or a minus sign. Table I illustrates the various numerical and mathematical characters and indicates the corresponding coil segment and external pin connections to which voltages must be applied to form each character.

* Tradename of Deerborn Glass Co., Chicago, Ill.

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TABLE I – PIN CONNECTIONS AND COIL SEGMENTS USED TO FORM DIGITAL-CHARACTER DISPLAY NUMITRON DIGITAL DISPLAY DEVICES

Display	Device Pin Designation				Corresponding Coil Segments			
	Pin No.2 Common For All Types							
	DR2000	DR2010	DR2020	DR2030	DR2000	DR2010	DR2020	DR2030
0	3,4,5,7,8,9	3,4,5,7,8,9			E,D,C,A,B,F	E,D,C,A,B,F		
1	5,8	5,8	6,8		C,B	C,B	D,C	
2	3,4,6,7,8	3,4,6,7,8			E,D,G,A,B	E,D,G,A,B		
3	4,5,6,7,8	4,5,6,7,8			D,C,G,A,B	D,C,G,A,B		
4	5,6,8,9	5,6,8,9			C,G,B,F	C,G,B,F		
5	4,5,6,7,9	4,5,6,7,9			D,C,G,A,F	D,C,G,A,F		
6	3,4,5,6,7,9	3,4,5,6,7,9			E,D,C,G,A,F	E,D,C,G,A,F		
7	5,7,8	5,7,8			C,A,B	C,A,B		
8	3,4,5,6,7,8,9	3,4,5,6,7,8,9			E,D,C,G,A,B,F	E,D,C,G,A,B,F		
9	4,5,6,7,8,9	4,5,6,7,8,9			D,C,G,A,B,F	D,C,G,A,B,F		
+			7,9	6,8			B,A	B,A
−			7	6			B	B
.		1				H		

Individual coil segments of types DR2000 and the DR2010 may also be addressed to provide other symbols and certain alphabetical displays. Table II illustrates ten nonconflicting letters that can be displayed on these devices and lists the corresponding coil segment and external pin connection to which voltages must be applied to form each of them.

Characters displayed on NUMITRON devices are shown in a height-to-width aspect ratio of approximately 2 to 1 within an over-all display area that has a nominal height of 0.6 inch and a nominal width of 0.35 inch. If larger characters are desired, the display may be viewed through a Fresnel lens that provices the required magnification. The light emitted from the incandescent coil segments has a very wide color bandwidth and, therefore, permits virtually an unlimited choice of color filters to obtain a display in any desired color. By variation in the magnitude of the coil-segment voltages, the brightness of the display is completely adjustable from zero light output to a level that is easily viewable under very high ambient-light conditions, even sunlight.

The application of voltages to individual coil segments to form the desired character is controlled by a decoder/driver circuit. One end of each coil segment is internally connected to a common lead. The external connection (pin 2) for this lead is usually the positive terminal for the segment voltages. The ground return (or negative connection) for the segment-voltage supply is completed through the decoder/driver.

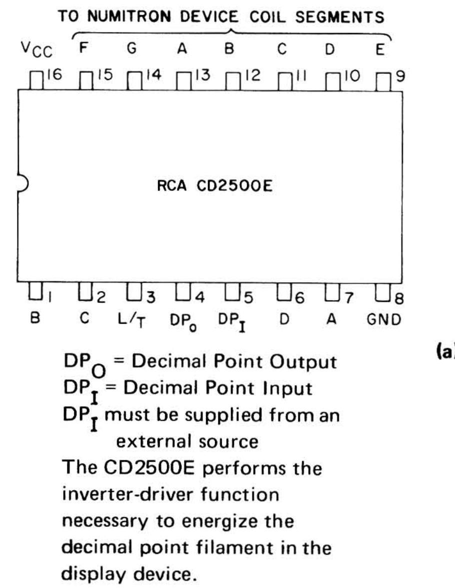
Two RCA 16-lead integrated-circuit decoder/drivers, types CD2500E and CD2501E, supplied in dual-in-line plastic

TABLE II – PIN CONNECTIONS AND COIL SEGMENTS USED TO FORM ALPHABETICAL DISPLAYS ON RCA DR2000 AND DR2010 NUMITRON DEVICES

Display	Device Pin Designation	Corresponding Coil Segments
	Pin No. 2 Common	
A	3,5,6,7,8,9	E,C,G,A,B,F
C	3,4,7,9	E,D,A,F
E	3,4,6,7,9	E,D,G,A,F
F	3,6,7,9	E,G,A,F
H	3,5,6,8,9	E,C,G,B,F
J	3,4,5,8	E,D,C,B
L	3,4,9	E,D,F
P	3,6,7,8,9	E,G,A,B,F
U	3,4,5,8,9	E,D,C,B,F
Y	4,5,6,8,9	D,C,G,B,F

packages, are available for use with the NUMITRON devices. Each type of decoder/driver accepts four inputs in BCD 8-4-2-1 code and provides 7-segment decoded outputs that represent a numeral from 0 to 9. Table III lists the BCD inputs and indicates the coil segments of the DR2000 that are illuminated to form each of the numerals 0 through 9. The decoder/drivers differ in that the CD2500E contains a decimal driver and the CD2501E has a ripple-blanking feature that automatically eliminates all insignificant zeroes in the multidigit numerical display. Fig. 3 shows terminal-connection diagrams for both integrated-circuit decoder drivers. (For more detailed information on the CD2500E and CD2501E, the reader should refer to the published data on these devices.)

Structural Features: The single-helical coil segments of the NUMITRON devices are rigidly supported by accurately positioned pins that protrude through a black substrate to form an in-plane structure for direct viewing. The in-plane viewing surface provides a display that is free of clutter and residual images. The black substrate forms a background that offers an excellent contrast to the display. In addition, the "up front" type of display surface makes possible a wide (140-degree) viewing angle.



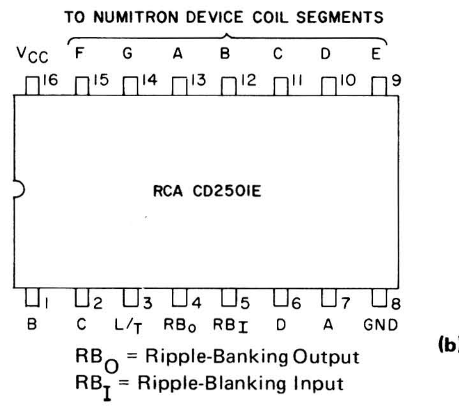


Fig. 3 - Terminal-connection diagrams for RCA integrated-circuit decoder/drivers: (a) CD2500E; (b) CD2501E.

The single-helical coil segments are made from a tungsten-alloy wire that is specially treated to prevent objectionable bowing of the coil segments during the life of the devices. The coil segments are connected to the lead wires by use of highly reliable welding techniques specifically developed for this purpose. The coil-and-substrate structure is firmly supported inside the glass envelope. Additional support is provided by the rugged, formed internal leads that are used to connect the coil segments to the external pin connections.

Coil segments operate at a temperature of approximately 1400°C, which is substantially less than the operating temperature (typically about 2500°C) of filamentary lamps. At this relatively low operating temperature, the vapor pressure of the tungsten-alloy wire is esentially zero so that evaporation of the coil segments is negligible. In addition, the low operating temperature and the relatively small mass of

TABLE III – DECODER INPUTS REQUIRED TO FORM NUMERICAL CHARACTERS ON THE DR2000 NUMITRON DIGITAL DISPLAY DEVICE

Display	BCD INPUT (8-4-2-1 CODE) TO DECODER/DRIVER			
	D (TERM. 6)	C (TERM. 2)	B (TERM. 1)	A (TERM. 7)
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

Notes: **1.** D, C, B, and A represent the BCD code 8-4-2-1, respectively, which are the four inputs to the decoder/driver required to illuminate the corresponding digit on the NUMITRON device.
2. 0 = low-level input; 1 = high-level input.

the coil segments assure that all other parts remain cool and, therefore, do not release any gas during operation. The typical envelope temperature of a NUMITRON device during operation is illustrated by Fig. 4, which shows that the bulb temperature is maintained at approximately 14°C above the ambient temperature. These factors and the efficient getter employed assure that the high initial vacuum will not be degraded during the useful life of these devices.

The use of the construction and processing techniques discussed in the preceding paragraphs result in highly reliable devices that have a very long operating life. The well-supported, single-plane type of structure used for these devices, together with the relatively small mass of the coil segments, results in extremely rugged devices that can safely withstand high levels of shock and vibration. The devices have a life expectancy greater than 100,000 hours when operated at segment voltages between 3.5 and 4.5 volts. At higher segment voltages, the operating life decreases approximately in proportion to the twelfth power of the applied voltage. The curve in Fig. 5 shows the relative

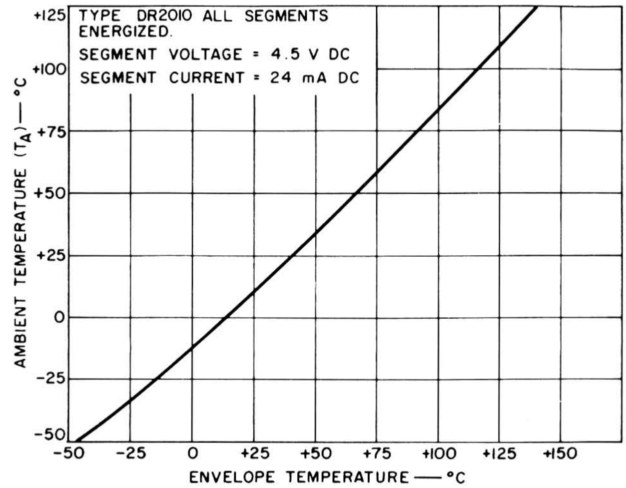


Fig. 4 - Envelope temperature of a NUMITRON device as a function of the ambient temperature.

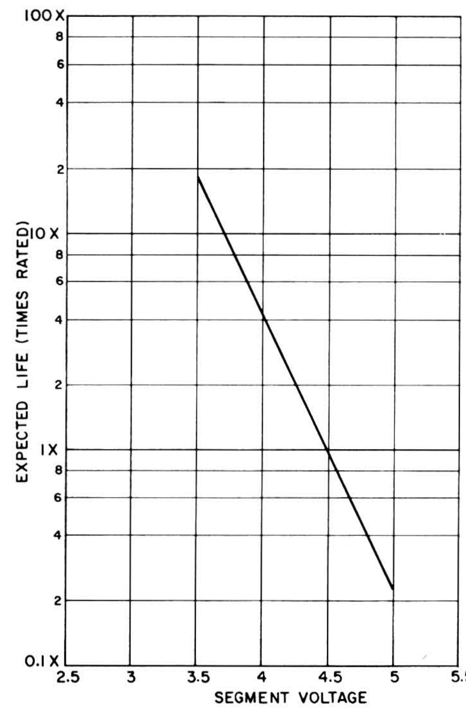


Fig. 5 - Relative life expectancy of NUMITRON devices as a function of coil-segment voltage.

life expectancy as a function of segment voltage. This curve is based on the twelfth-power rule, which is generally accepted in the industry for tungsten wire.

MOUNTING

The glass envelope used for NUMITRON devices employs a standard miniature 9-pin base configuration. These devices, therefore, can be mounted in the existing low-cost sockets normally used for miniature electron tubes. If desired, the devices may be mounted, with a minimum center-to-center distance of 0.80 inch, on printed-circuit boards by use of direct soldering or by use of a commercially available socket, as shown in Fig. 6.

Fig. 6(a) shows a suggested layout for mounting a NUMITRON deivce directly on a printed-circuit board. This layout also shows the mounting arrangement for the CD2501E integrated-circuit decoder/driver and the required interconnection printed wiring. The view shown is of the bottom (copper side) of the printed-circuit board. The mounting holes shown for the device pins should be made with a No.57 (0.043-inch-diameter) drill.

The pin-circle diameter of the NUMITRON devices is 0.468 inch, and the center-to-center distance between adjacent devices is 0.80 inch. The line width of the conductors is 0.025 inch. The width of the common bus for pin 2 is determined by the number of devices used. A 0.100-inch-wide bus will handle up to five devices. The outside diameter of the pads for the NUMITRON devices is 0.94 inch.

Fig. 6(b) shows a layout for mounting a NUMITRON device and CD2501E decoder/driver on a printed-circuit board when a commercial socket, Mcthod Manufacturing No. PN-8610 or equivalent, is employed. This layout is very similar to that used for direct mounting, shown in Fig. 6(a). Line widths and spacings of the interconnection wiring and pad diameters are the same. The mounting holes shown for the socket leads should be made with a No. 56 (0.465-inch-diameter) drill.

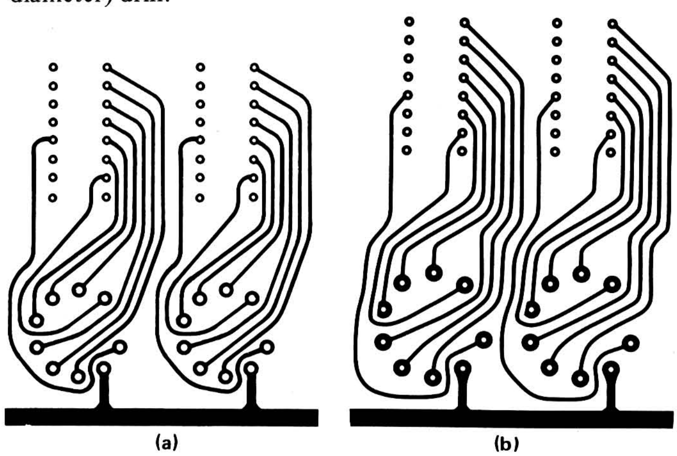


Fig. 6 - Printed-circuit-board layouts for two NUMITRON devices and associated CD2501E integrated-circuit decoder/driver: (a) direct-mounting arrangement; (b) with NUMITRON devices mounted in a commercial socket.

DC OPERATION

NUMITRON devices are designed for optimum operation at a segment voltage of 4.5 volts. This value of voltage results in a nominal segment current of 24 milliamperes and an average power dissipation of 108 milliwatts. Satisfactory operation in relation to brightness of the display and operating life is maintained for any value of segment voltage between 3.5 and 5 volts. (For multiplex operation, segment voltages greater than 5 volts may be used provided that the appropriate duty factor is observed.)

Fig. 7 shows a simple test circuit that may be used to determine the current and luminance of individual coil segments as a function of segment voltage. Figs. 8 and 9 show the variations in these quantities with changes in the segment voltage.

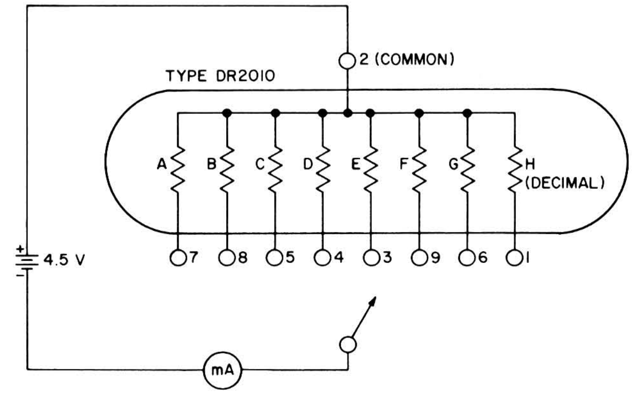


Fig. 7 - Test circuit used to determine current and luminance characteristics of individual coil segments as a function of segment voltage.

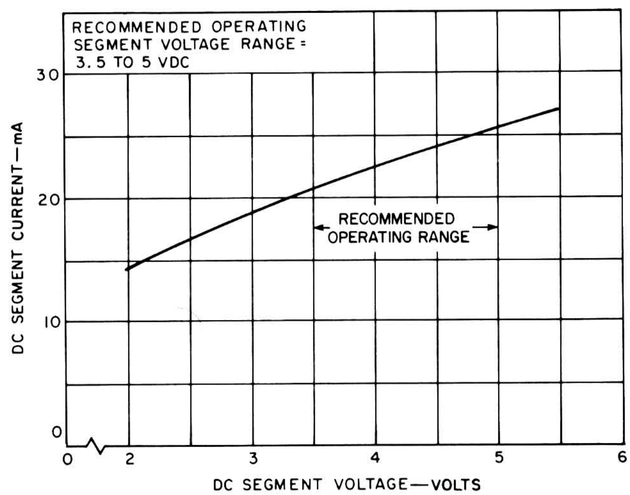


Fig. 8 - Direct current through a coil segment as a function of the segment voltage.

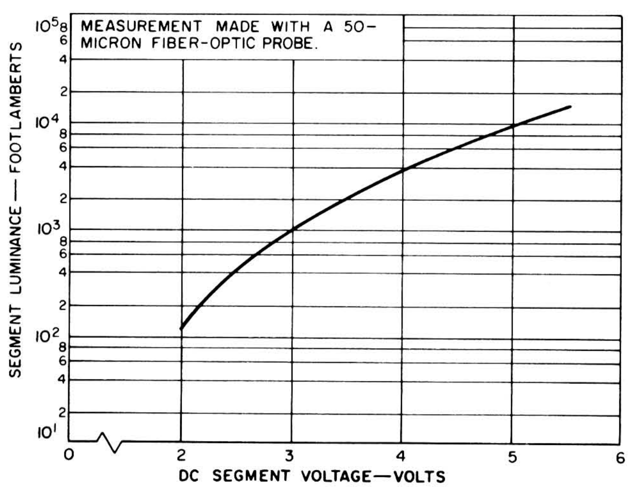


Fig. 9 - Luminance of a coil segment as a function of the segment voltage.

Fig. 10 shows the basic interconnection of a NUMITRON device with an integrated-circuit decoder/driver for operation from a fixed dc supply. During circuit operation, 0.3 to 0.5 volt is dropped across the decoder/driver. A dc supply of 5 volts, therefore, is required to obtain the desired segment voltage of 4.5 to 4.7 volts. For fixed-brightness operation, the device may be operated directly from the 5-volt V_{CC} supply of the integrated-circuit decoder/driver. If a controllable brightness is desired, a separate power supply is recommended.

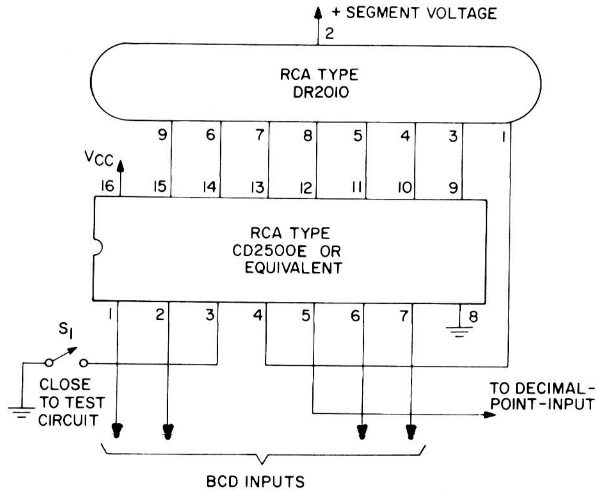


Fig. 10 - Basic interconnection of a NUMITRON device with an integrated-circuit decoder/driver.

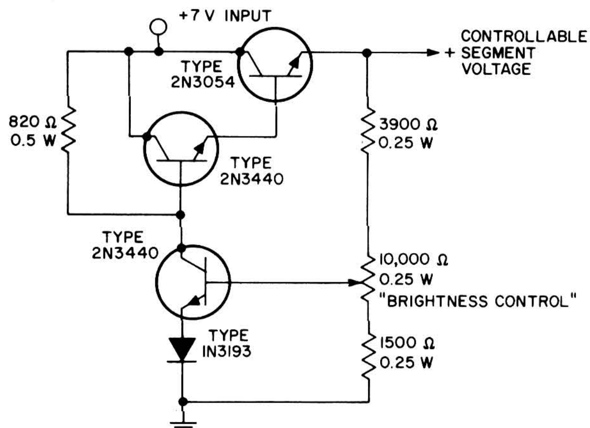


Fig. 11 - Series regulator circuit used to provide brightness control for NUMITRON devices.

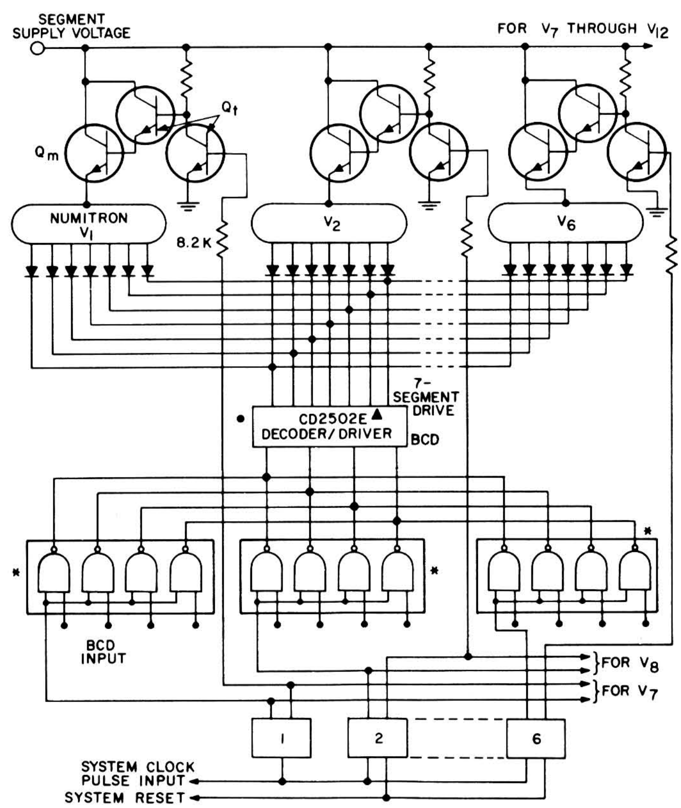
Fig. 11 shows a schematic of a simple series voltage-regulator circuit that may be used to control the brightness of the NUMITRON device display. The circuit operates from a dc input of 7 volts and provides a variable dc voltage output of approximately 2.5 to 5 volts. With this variable voltage applied to the common coil-segment connection (pin 2) of a device, the brightness of the display can then be varied by adjustment of the brightness-control potentiometer in the regulator circuit.

MULTIPLEX OPERATION

From a design and reliability standpoint, it is usually desirable to use one decoder/driver for each readout device. However, when a display requires more than six readout devices, the use of one decoder driver for multiplexing can result in a significant cost advantage. The present cost of a decade that consists of decoder/driver and a readout device provides supporting evidence for this statement. The technological advances being made in integrated-circuit manufacturing should result in significant reductions in the costs of the decoder/drivers. With increased volume, it is even possible that the low cost of NUMITRON devices may be further decreased. It is highly probable, therefore, that during the next several years, the cost of the decade will be reduced to a point at which the multiplex mode of operation then will no longer offer a significant advantage.

In the conventional direct-drive method of operation, a given number of NUMITRON devices require an equal number of decoder-drivers for the simultaneous display of the numerical output data. In the time-multiplex system, however, one decoder-driver can be made to drive a number of readouts sequentially. If the multiplexing repetition rate is greater than 50 Hz, there is no appreciable flicker of the numerals being displayed.

One possible method of multiplex operation is illustrated by the basic block diagram shown in Fig. 12. In this circuit, one RCA CD2502E decoder/driver is used to drive up to a maximum of six DR2000 devices with a duty factor of 16.2 per cent. When DR2010 devices are used, a separate drive circuit for the decimal points will have to be incorporated. The multiplex circuit incorporates a ring counter which, in sequence, controls the BCD data in the



* CD2302 or equivalent

▲Selection of the CD2502E rated for operation at 12 volts.

● The CD2502E can drive up to six readouts. Eight NUMITRON devices may be multiplexed provided that a suitable decoder/driver (rated for operation at 15 volts and 60 milliamperes) is used. Required decoder/driver ratings are determined from Fig. 14.

Fig. 12 - Basic components required for multiplex operation of NUMITRON devices.

NAND gates and the application of the segment-voltage pulses, which pass through a drive transistor Q_m, to the common terminal of each device. In this way, the ring counter determines which device in the series will provide the proper numerical display at a given time. The illumination of the proper coil segment to form the desired numeral on each device is still controlled by the decoder/driver in response to the BCD coded inputs. Isolation diodes are needed in series with each coil segment to prevent simultaneous lighting of coil segments in adjacent devices.

As shown in Fig. 13, multiplex operation of the NUMITRON devices is possible at pulse voltages significantly higher than the maximum recommended value of 5.0 volts specified for dc operation, provided at the appropriate duty factor is observed. During this operation, however, care should be

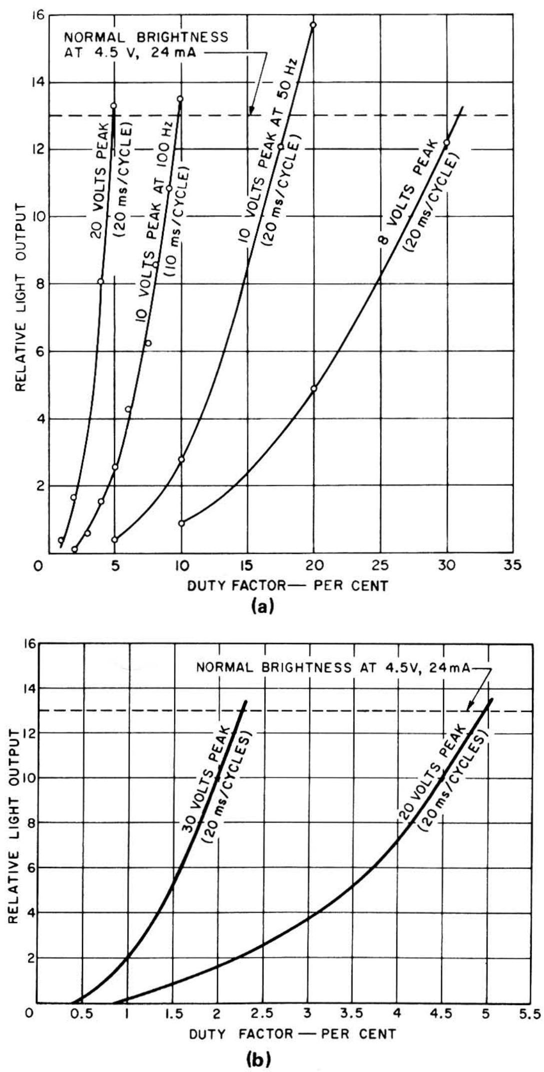


Fig. 13 - Relative light output of NUMITRON devices as a function of duty factor and pulse magnitude for multiplex operation.

taken to ascertain that the breakdown voltage rating and the maximum output current rating of the decoder/driver will not be exceeded. Also, transistor Q_m should be carefully selected to ensure that it can handle the maximum current required. Fig. 14 shows the peak voltage (E_p) and current (I_p) of the NUMITRON device for various duty cycles.

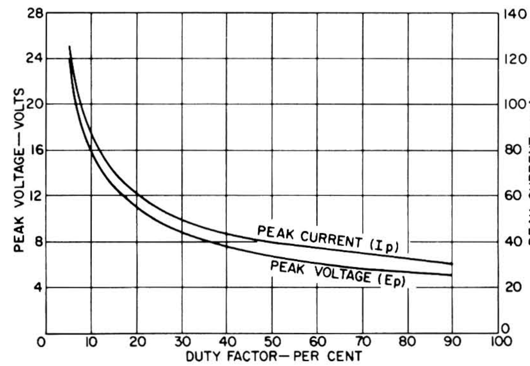


Fig. 14 - Peak pulse voltage and current required to produce a readout display of the same brightness as a dc segment voltage of 4.7 volts as a function of duty factor.

USE OF NUMITRON DEVICES IN DIGITAL COUNTER/ TIMERS AND DIGITAL VOLTMETERS

By far, the most common digital measuring instruments are the digital counter/timer and the digital voltmeter (DVM). A brief discussion of each is followed by a description of considerations necessary for conversion of present designs to NUMITRON display devices and for the use of these devices in new designs. This information is widely applicable to other types of digital instrumentation.

Counter/Timers: Digital electronic counter/timers are the most accurate and convenient instruments for measurements of frequency and time intervals. During operation as a counter, shown in Fig. 15, the main gate is opened for a precise period of time, as controlled by a crystal oscillator and decade dividers. During the gating interval, the number

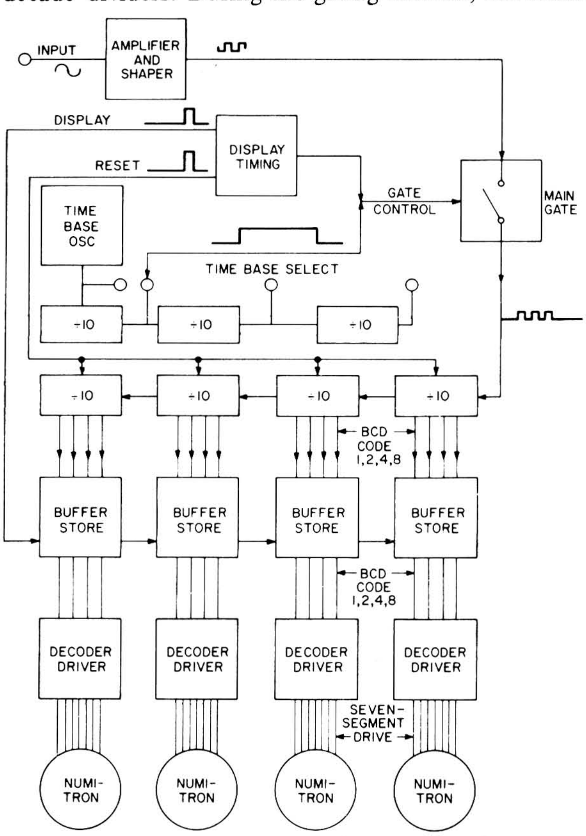


Fig. 15 - Digital counter/timer using NUMITRON devices to provide the visual readout operated as a counter.

of input cycles are totaled in the decade counter assembly and displayed on the NUMITRON devices. The display timing control selects the sample rate, resets the counters, and operates the buffer/store which stores one count while the next count is being made by the decade drivers. The output (BCD 8-4-2-1 Code) of the buffer/store controls the decoder/driver which, in turn, lights the proper segments of the NUMITRON device.

Digital Voltmeters: Digital voltmeters represent the fastest growing group of electronic instruments. These devices make possible a digital reading of ohms, ac and dc voltages and currents in a convenient accurate manner. Seven different methods can be used to digitalize the analog input signals: ramp, staircase ramp, dual slope integrating, integrating, integrating and potentiometric, successive approximation, and continuous balance. All these methods, however, require digital readouts and counting similar to that of the simple ramp method shown in Fig. 16. In the ramp method, the dc signal is compared against an accurate ramp. The width of the output signal is proportional to the dc voltage being measured. The comparator output operates a gate that allows a number of oscillator cycles through the gate in direct proportion to the input voltage. With 1 volt at the input, exactly 1000 cycles pass through the gate and are totaled on the counters. Similarly, an input of 0.500 volt results in exactly 500 counts. The display timing circuit operates the buffer/store which causes the new reading to be displayed. The extra digit "1" and the polarity information are displayed on the RCA DR2020 and are controlled as shown in Fig. 16.

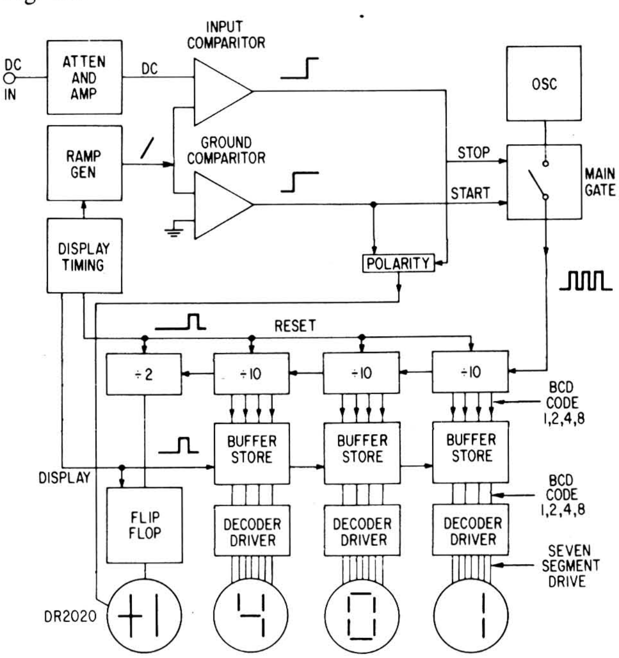


Fig. 16 - Ramp type of digital voltmeter using NUMITRON digital display devices to provide the visual readout.

Decade Counter Assemblies: Both the digital voltmeter and the digital counter contain decade counter assemblies and consist of a divide-by-10 counter, a buffer/store, a decoder/driver, and a visual readout. The BCD output of the decade counter changes continuously during counting. These signals are applide to the buffer/stroe which consists of four storage flip-flops which are controlled so that they store only the resultant total and ignore the intermediate changes. A change appears in the BCD output of the buffer/store only when the new final count differs from the preceding one. This BCD output is connected to the decoder/driver and sometimes to external terminals for interconnection with digital computers and other digital equipment. The decoder/driver converts the BCD input into a 7-line output that lights the appropriate segments of the device.

Elimination of the Buffer/Store in the Digital Voltmeter: As previously mentioned, the purpose of the buffer/store in the digital voltmeter is to store the final count from the last measurement while a new measurement is being made. This action prevents visual flicker during counting and presents an external BCD output that is unaffected by the measurement or totaling methods used. It is frequently desirable, however, to remove the buffer store in low-cost digital voltmeters. This removal is permitted if the totaling is done very rapidly, and the last count is then held for a period of time. If the proper ratio of the counting interval to the total interval (duty cycle) and the rate of measurement are maintained, flicker can be avoided. It is recommended that this duty cycle be less than 10 per cent. Fig. 17 shows a typical input to the decoder/driver when the buffer/store is not used.

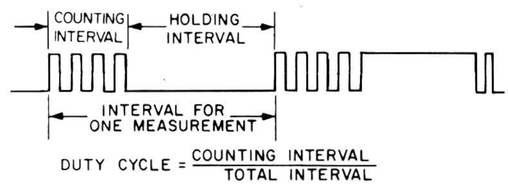


Fig. 17 - Typical input to the decoder/drivers of a digital voltmeter when the buffer/store feature is not used.

Elimination of the Buffer/Store in the Counter/Timer: In the counter/timer, the counting rate and gate time are not fixed but vary with the signal being counted. At low frequencies, the gate time becomes long, and the counting rate slow. Without a buffer/store, changing numerals must be tolerated or the display must be shut off during the counting period which results in a blinking effect. Turning off the display is easily accomplished by grounding the intensity control input of the CD2501E decoder/driver or by disconnecting the display supply voltage. When no buffer/store is used, flicker appears to be less annoying than that of a gas-discharge type of readout.

NUMITRON Device Characteristics: Because of the nonlinear optical and thermal characteristics of these devices, the light output varies with both duty cycle and applied voltage, as shown in Fig. 13.

Characteristics of the NUMITRON devices are such that if the applied voltage is turned on and off at a rate less than about 50 times per second there is a noticeable flicker. When used in a counting operation, some segments are operated three times while others operate eight times in going from 0 through 9. At slow counting rates, therefore, some segments may appear dim, or flicker, unless buffer/store is used.

If the measurement rate is kept above 50 Hz, then the NUMITRON will appear to be on continuously.