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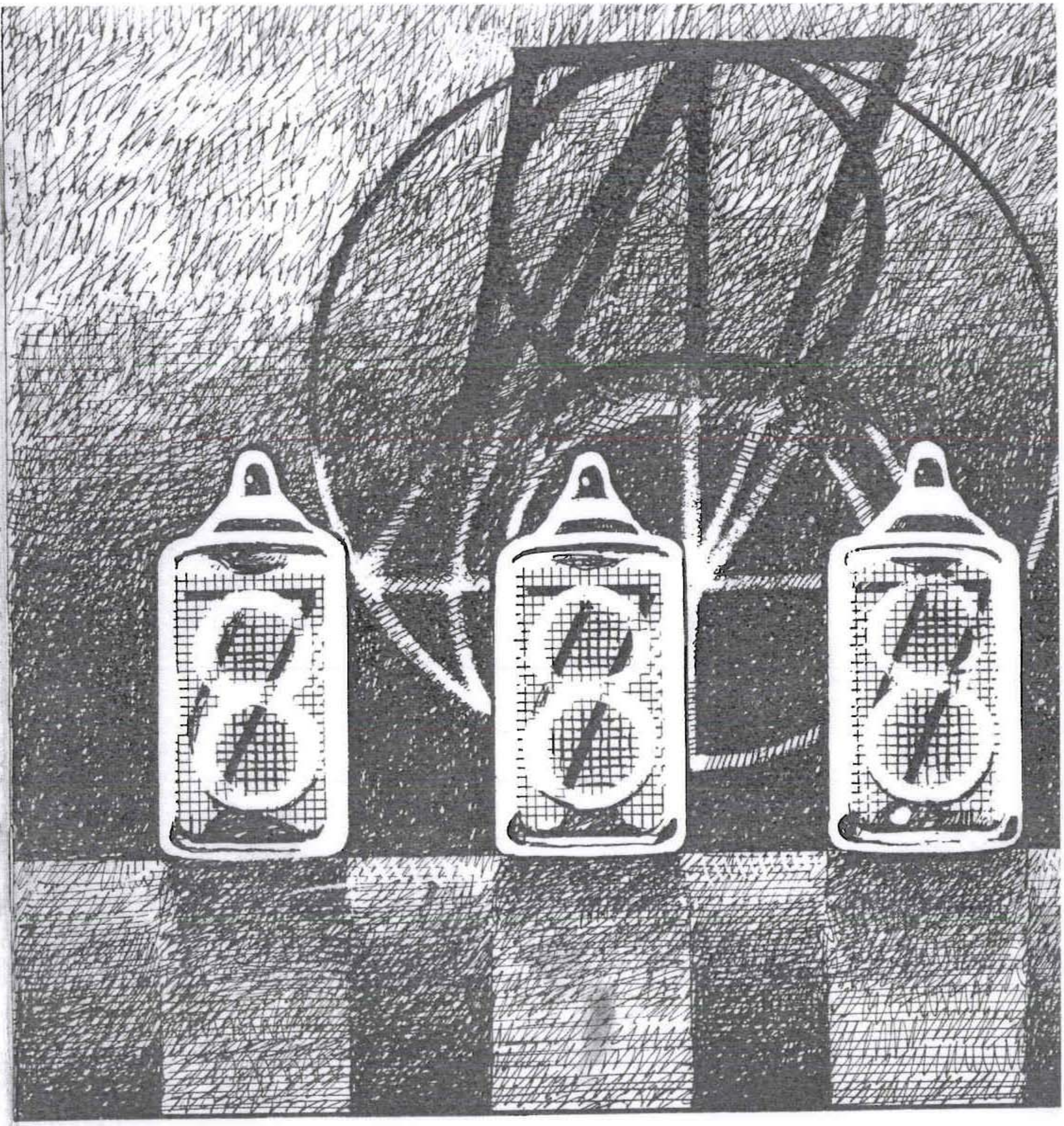
Document in this file	ITT - Cold-cathode Indicator Tubes Application Notes 1972
Display devices in this document	5853S, 5870S, 58GA-S, 58GR-S, 58GS-S, 5960-99-1711-0174, CV5278, CV5351, CV8572, CV9316, GN-13, GN-13A, GN-4, GN-4A, GN-4P, GN-5, GN-5A, GN-6, GN-6A, GN-9, GN-9A, GNP-17, GNP-17A, GNP-4A, GNP-7, GNP-7A, GS-17, GS-17A, GS-4, GS-4A, GS-6, GS-6A



Cold-cathode Indicator Tubes Application Notes 1972

COMPONENTS ITT

6335/565E

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Introduction

This publication describes a range of long-life, gas-filled, cold cathode tubes which are designed to display information such as the state of a counter circuit or the position of a selector switch.

Each tube has an anode and a number of cathodes, the latter being of the physical shape of the characters to be displayed. On the application of a voltage between the anode and a selected cathode, the cathode glows to display the character required.

These indicator tubes, which in themselves do not perform the function of counting, may be operated by :

- Transistors
- Relay contacts
- Gas-filled valves
- Amplifier valves
- Photo-resistors
- Beam switching devices

The tubes may be used in a variety of equipments including :

- Electronic data handling systems
- Measuring apparatus
- Machine control systems
- Signalling circuits
- Calling systems and similar equipment
- Lift indicators
- Telecommunications channel indicators
- Aircraft and train movement displays

Most basic types of tube can be supplied with either a clear bulb or with the bulb red-lacquered to filter out the slightly blue content of the discharge and to increase the visual contrast between the discharge and its surroundings. In this connection, an alternative method is the use of a circularly polarised filter : this considerably enhances the display by eliminating tube reflections due to external illumination.

Abridged Data

The following table gives quick-reference data for the current range of indicator tubes.

Please note that additional types of indicator tube which display other letters, digits, fractions or combinations of these characters can be supplied in commercially worthwhile quantities.

The following accessories are available as separate items :

MG6A Tube mounting bracket.

For use with GN-6, GN-9, GNP-7 and GS-6 types of tubes.

MG8 Base wire spreader.

For use with tubes with flying leads. The spreader gives a wire spacing of 0,1 inch (2,54mm) for printed circuit board use.

SK207 Tube socket.

For use with 5853S, 5870S, 5856, 5856S, 58GA-S, 58GR-S, 58GS-S.

Type	CV/JS Number	Characters Displayed		I_k average max		Base
		Description	†Height (mm)	Digits/ Symbols (mA)	Decimal points (mA)	
Side-view Tubes						
5853S 5870S		0 to 9 inclusive and two decimal points	13	4,0	0,3	Short leads
58GA-S		Symbols V A Hz Ωs	11	4,0		Short leads
58GR-S		Symbols M k μ m	11	4,0		Short leads
58GS-S (Note 1)		Symbols + − ∼	11	4,0		Short leads
GN-6* GN-6A GN-9* GN-9A		0 to 9 inclusive	14	2,5		Flying leads
GNP-7* GNP-7A		0 to 9 inclusive and two decimal points	16,5	3,0	0,5	Flying leads
GN-13* GN-13A		0 to 9 inclusive	16,5	3,0		Flying leads
GNP-17* GNP-17A		0 to 9 inclusive and one decimal point	15,5	3,0	0,5	Flying leads
GS-6* GS-6A		Symbols + − ∼	9	3,0		Flying leads
GS-17* GS-17A		Symbols + − ∼ ⏀	10	2,5		Flying leads
End-view Tubes						
GN-4* GN-4A	CV5278, CV9316	0 to 9 inclusive	16,5	3,0		B13B
GN-4P* GNP-4A	5960-99-1711-0174	0 to 9 inclusive and one decimal point	16,5	3,0	0,5	B13B
GS-4* GS-4A	CV8572	Symbols V A + − Ω % ∼	15,4	3,0		B13B
GN-5* GN-5A	CV5351	0 to 9 inclusive	26	5,0		B12A

†Luminous size. *Bulb is red-lacquered.

Note 1. In addition to the symbols mentioned, a fault symbol, probably spiral in shape, will be incorporated.

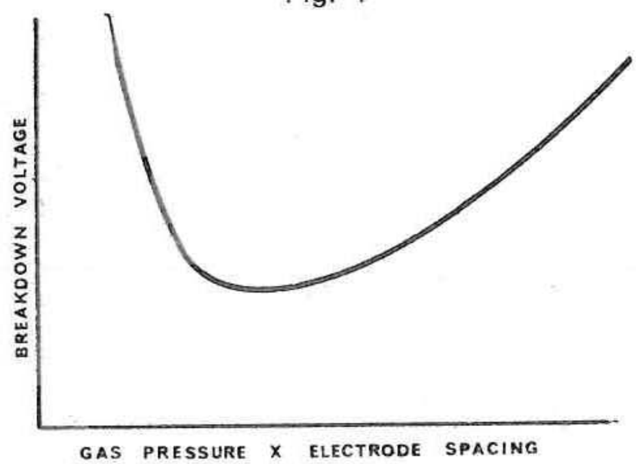
Basic Theory of Indicator Tube Operation

Ignition

If, as in indicator tubes, two or more electrodes are sealed into a space occupied by a rarified gas (for example, at about 10 torr pressure), the electric current flow between any pair of electrodes will be negligible until the voltage difference between them exceeds a critical value related to the product of gas pressure and electrode spacing.

In an indicator tube, where the electrodes are extended into the shapes of characters to be displayed, there is usually an anode-cathode spacing which corresponds to the minimum breakdown voltage for a given gas pressure. See Figure 1.

Fig. 1



Before this critical voltage is reached, the current flow is due only to the migration of electrons and positive ions generated by external sources such as cosmic rays or, in some cases, by internal radioactive priming.

After the critical voltage has been passed, the electron and ion velocities are sufficient to produce cumulative ionisation by inelastic collision between atoms and fast-moving electrons due to secondary emission from the ion-bombarded cathode. The resulting Townsend avalanche current is limited principally by the circuit impedance external to the tube.

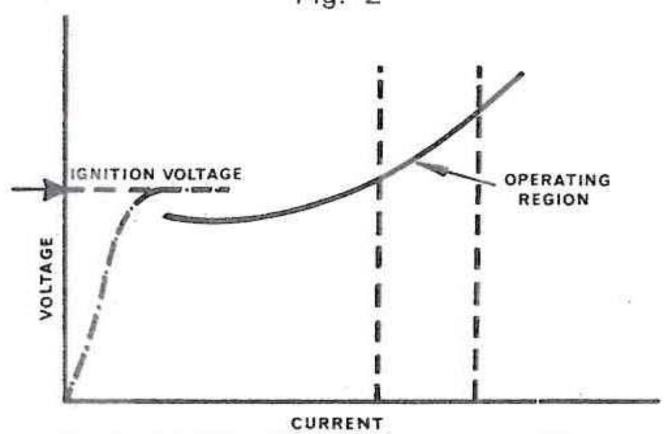
Glow Discharge

If the current which flows is limited to the order of milliamperes, the discharge occurs in the glow mode which is characterised by a voltage drop largely independent of current flow. This maintaining voltage is not dropped evenly across the space between anode and cathode, but mostly in the cathode region where the glow is most intense and takes up the shape of the cathode.

Once the cathode is fully covered, the abnormal glow condition is reached and any increase in current will cause the maintaining voltage to rise. It is necessary to operate character indicator tubes at a current above the minimum for full cathode coverage. The maintaining voltage at the operating point may be higher than the initial ignition voltage. See Figure 2.

If the voltage across the tube is reduced to a value below the maintaining voltage the tube will extinguish.

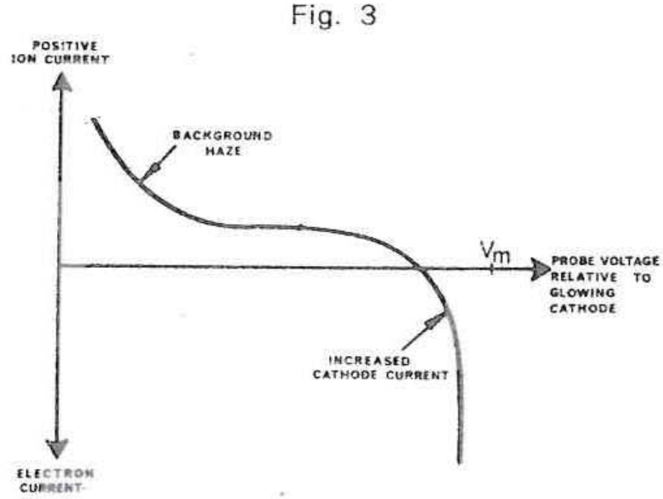
Fig. 2



Probe Effects

In multi-electrode tubes, such as indicators, the discharge pattern may be modified by the potentials applied to the electrodes other than the anode and the cathode selected for conduction. The other electrodes will collect electrons or positive ions to an extent governed by their distance from the discharge path and by their potentials relative to a critical value slightly below the maintaining voltage. (See Figure 3.) Open circuit probes will naturally take up this critical potential.

Fig. 3



If the other electrodes collect electrons appreciably, the cathode current will be increased and a stage may be reached at which the dissipation of the cathode exceeds a safe limit.

If they collect positive ions, the visible glow will spread to them to some extent. For small currents this may produce a negligible effect, but if the amount is excessive it will produce a background haze which, in the extreme, will effect the illumination of more than one cathode. The transfer of discharge from one cathode to another is a matter of change in relative applied potentials.

In indicator tubes the cathodes are distributed in mutual proximity and the glow is transferred by adjustment of their relative potentials.

Indicator Tube Characteristics

Ignition Voltage

Ignition voltage, also referred to as striking voltage, is the voltage which has to be applied between the anode and a given cathode to start a cathode glow discharge. It is a d.c. potential applied so that the anode is positive with respect to cathode.

The structure of indicator tubes is such that the value of ignition voltage is not much different from that of the voltage drop across the tube when the cathode is covered with glow.

Maintaining Voltage

This is the potential occurring between cathode and anode, after ignition, which results from current conduction. It is a function of cathode current and cathode shape. Since the shapes of individual cathodes in an indicator tube differ considerably, it is inevitable that the maintaining voltage for a given cathode current will vary from cathode to cathode more than in cold-cathode devices in which the cathodes are identical.

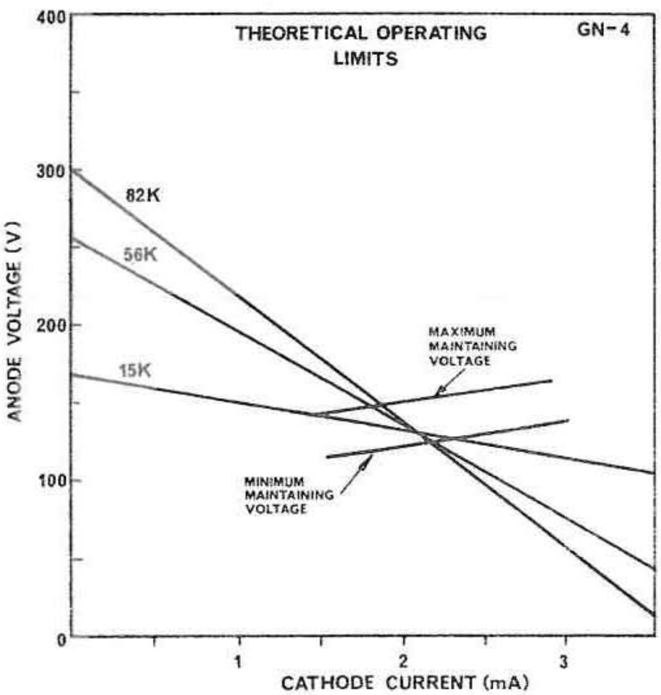
Supply Voltage

This is the source from which the other voltages are derived. It includes voltages dropped across series circuit components such as the current limiting resistor. Usually it is a direct voltage and essentially of higher value than either the ignition or the maintaining voltages. Greater constancy of current, either between individual cathodes in a tube or from tube to tube of a given type, will be achieved by the use of high values of supply voltage and corresponding high values of series resistance.

When an indicator tube incorporating an optional decimal point character is used, the tolerance of the anode resistor value should be closer than that for other tubes. This is because the main character cathode current, in addition to coping with the worst conditions of resistance tolerance, anode supply tolerance and tube glow maintaining voltage, must vary between a value when the decimal point is switched off and a value of from 0,2 to 0,5mA lower when the decimal point is switched on. Thus the nominal value of the resistor should be chosen to give a cathode current on the higher side of mean for the decimal point 'off' condition.

Figure 4 shows the relationship between supply voltage and cathode current for the GN-4 type of tube. A load line drawn through the supply voltage point on a V_a/I_a graph will cut the maintaining voltage curve at the operating point.

Fig. 4



Bias Voltage

A non-conducting cathode, in association with a conducting cathode and anode, will assume a potential which is between the potentials of the other electrodes.

Alternatively a predetermined voltage may be applied to the non-conducting electrode. This is termed the bias voltage. Its value will be related to operating conditions : a high value will give less spurious discharge but will require switching components with higher voltage ratings.

Extinguishing Voltage

This is the value to which the voltage between a conducting cathode and the anode must be reduced to interrupt conduction, and thus cathode glow.

Cathode Current

The coverage of the cathode electrode by discharge glow is dependent upon the cathode current. Accordingly, the minimum current for full coverage is an important characteristic and is given as a d.c. value. Under pulse conditions the mean value of current may be less than the minimum current to cover, as long as full coverage is achieved by the peak pulse value.
Pulse current operation will arise from the use of rectangular pulses or of unsmoothed rectified alternating current.

Bulb Temperature

The recommended range of bulb temperature during operation is −20°C to +70°C. At temperatures below 0°C there are likely to be wider variations in tube characteristics and the life of the tube will be shortened : some condensation of mercury may occur but this disappears when the tube is operated.

Life Behaviour

All indicator tubes in the current range have a special gas filling and processing to ensure that long life will be obtained.
Typical expected lives are :
30 000 hours at the recommended d.c. mean operating currents with the discharge stepped to the next cathode at least once in every 100 hours. 5 000 hours at the recommended d.c. mean operating current on any one cathode.
Catastrophic failure of an indicator tube is very unlikely : gradual failure shows as an incomplete coverage of the character by the discharge which gives adequate warning that a replacement is required.

Supply Voltage for Indicator Tubes

Direct Voltage

The ideal supply for an indicator tube is a smooth direct voltage the value of which well exceeds the minimum specified. This, together with suitably chosen limiting resistors, will give well-defined cathode current values. A typical basic direct voltage circuit is shown in Figure 5.

Direct Voltage with added Bias

In this case the primary supply is a direct voltage and a pre-bias voltage is applied to the cathodes. The voltage being switched is not the full supply voltage, as in Figure 5, but only that necessary to reduce a cathode potential to the point of transfer. The tube is not being completely extinguished and re-struck. A typical circuit is shown in Figure 6.

Fig. 5

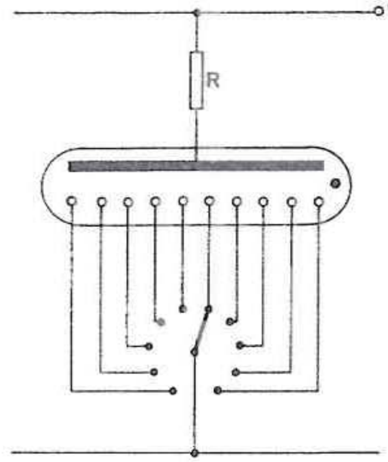


Fig. 6

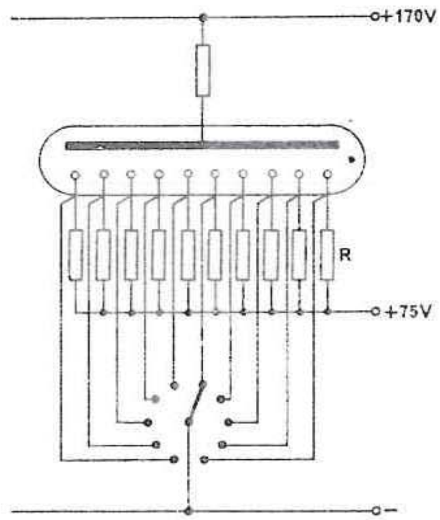
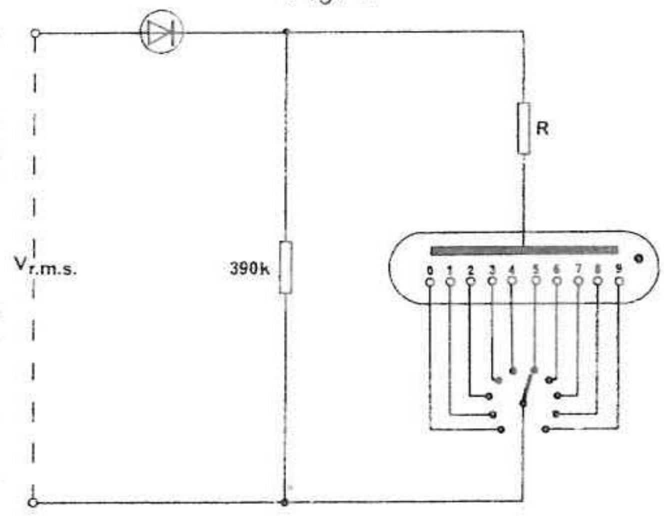


Fig. 7



Rectified Unsmoothed Sine-wave Voltage

Indicator tubes may be operated from rectified alternating supplies. In some cases this may lead to a simplification of power supply design.

Since the rectified waveform will usually be a positive half sine wave, the indicator tube will pass a current for less than half the total time involved. For the same apparent brightness of display, the values of peak current will be considerably greater than the current under direct voltage supply conditions.

Half-wave Rectified Supply

For this form of supply the indicator tube should be shunted by a resistor, the value of which is low compared with the back resistance of the rectifier: this is to avoid haze by reverse conduction of the tube. A typical circuit is given in Figure 7. The value of resistor R should be about half of that shown in Figure 11.

Full-wave Rectified Supply

With a full-wave rectified supply, transformer tappings can be used to provide cathode bias voltages which rise and fall in phase with the anode voltage. A typical circuit is given in Figure 8.

The strike and maintaining voltages of indicator tubes are approximately equal. By assuming they are exactly equal, the formulae for calculating the mean and r.m.s. currents are much simplified.

The cathode coverage is determined by the peak cathode current

$$i = \frac{\hat{V} - v}{R} \text{ (where v=maintaining voltage)}$$

The brightness of display is determined by the average cathode current which for full-wave conduction is given by:

$$I = \frac{2}{\pi R}\int_0^\theta (\hat{V}\cos\omega t - v)\, d\omega t$$

$$= \frac{2\hat{V}}{\pi R}\int_0^\theta (\cos\omega t - \cos\theta)\, d\omega t$$

$$= \frac{2K}{\pi R}\left(\hat{V} - v\right)$$

$$\text{where } K = \frac{\sin\theta - \theta\cos\theta}{1 - \cos\theta}$$

A plot of K versus θ is shown in Figure 10(b) overleaf.

Fig. 8

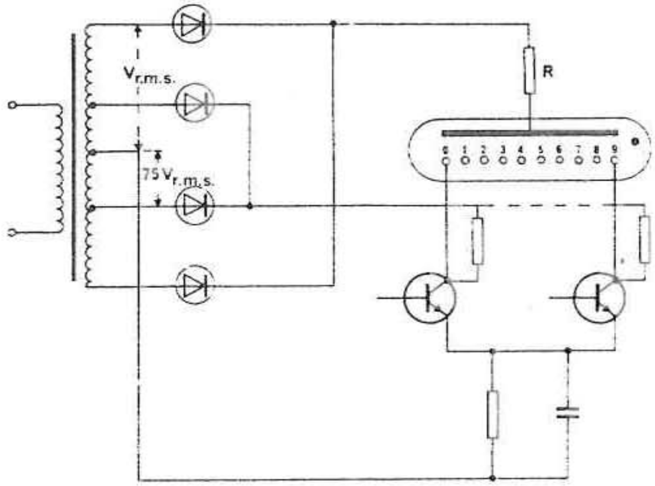


Fig. 9

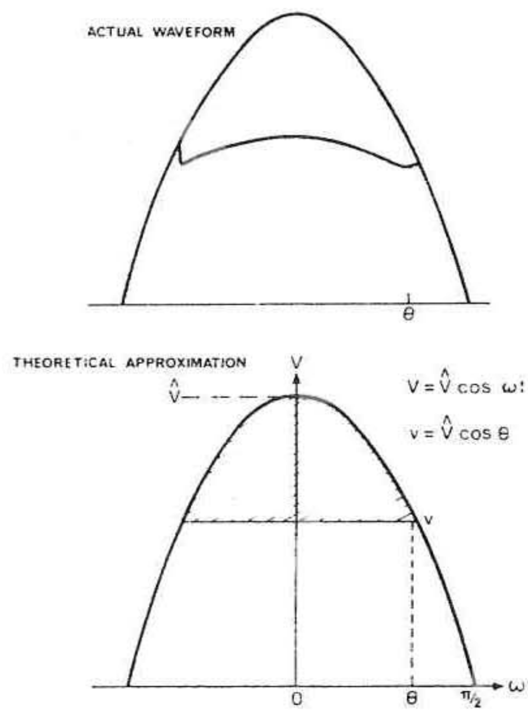


Figure 11 shows a plot of resistance R versus $V_{r.m.s.}$ $(\hat{V}/\sqrt{2})$ for constant current calculated with v=140V which, under peak current conditions, is approximately correct for the indicator tubes being described.

Preferred values of resistors are shown which allow margins for resistor tolerances, variations of maintaining voltage from cathode to cathode and from tube to tube, and the error due to the non-rigorous mathematical treatment above.

The power dissipation in the resistor is determined by the r.m.s. current given by:

$$\bar{I} = \frac{\left\{ \hat{V}^2 \int_{-\theta}^{+\theta} (\cos \omega t - \cos \theta)^2 \, d\omega t \right\}^{\frac{1}{2}}}{\left\{ R^2 \int_{-\pi/2}^{+\pi/2} d\omega t \right\}^{\frac{1}{2}}}$$

$$= \frac{\sqrt{A - B}}{R}$$

where $A = \frac{\theta}{\pi} (V^2 + 2V^2)$. and $B = \frac{3\hat{V}v \sin \theta}{\pi}$

The ratio $I_{r.m.s.}/I_{av.}$ varies from approx.

1,6 at $\theta = 45°$ to 1,1 as $\theta \rightarrow 90°$

This is illustrated in Figure 10(a)

Fig. 10(a)

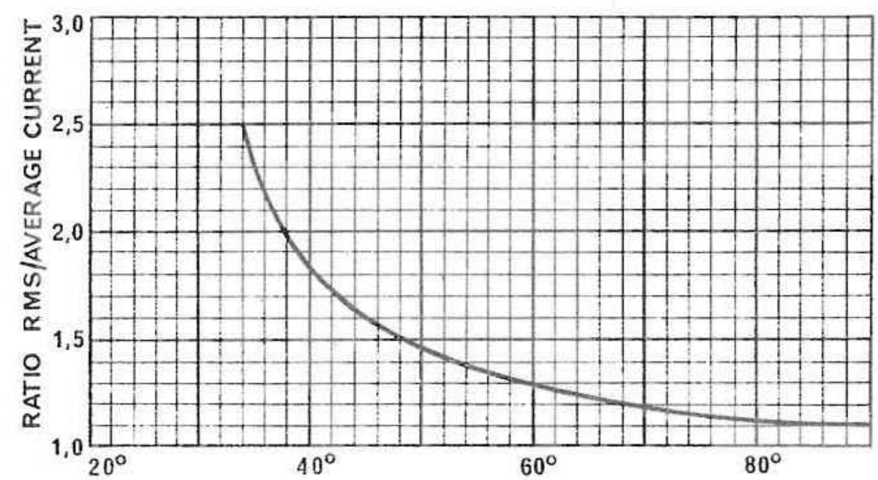


Fig. 10(b)

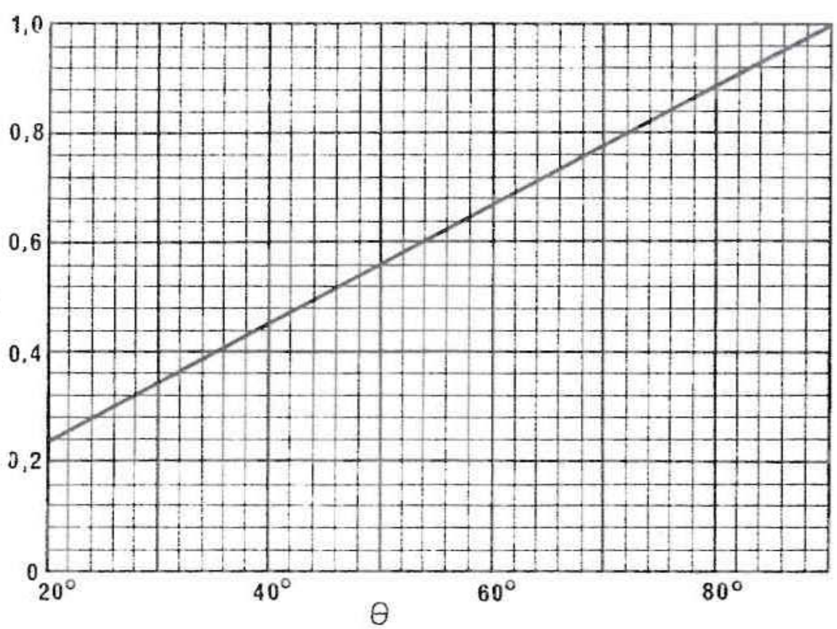
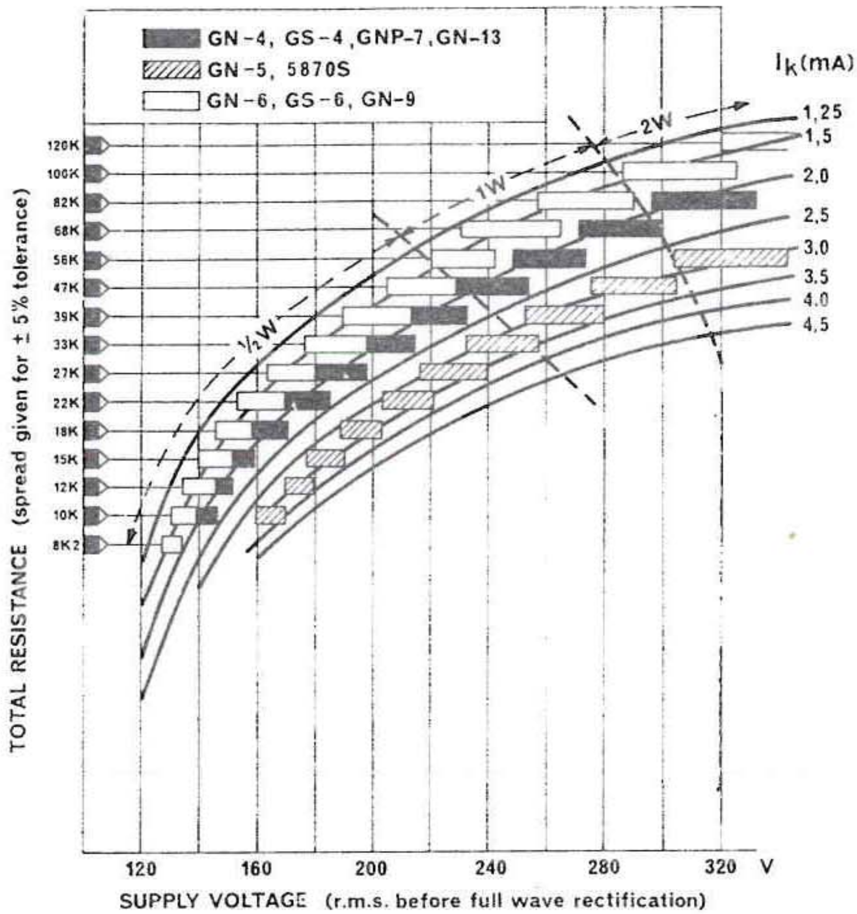


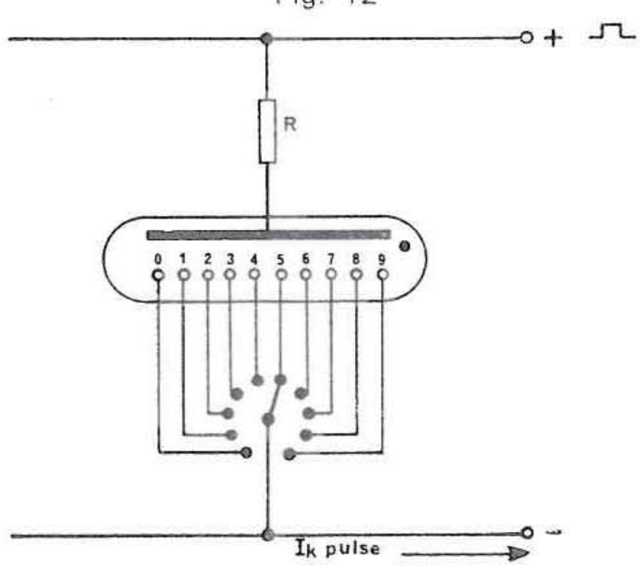
Fig. 11



Pulsed Supply

In its simplest form, pulse operation is as shown in Figure 12. It is simply an extension of the rectified sine wave technique. In practice this form of operation is coupled with the use of an advanced form of switching.

Fig. 12



Methods of Controlling Indicator Tubes

Direct Switching

A manual selector switch, uniselector or series of relay contacts may be used to connect to the selected cathode, the non-operating cathodes remaining disconnected. The prime requirement with this method of switching is that the contacts of the switching device are rated to operate at the maximum indicator tube anode voltage and at currents up to 5mA. Figures 13 and 14 show basic circuits employing a manual switch and uniselector mechanism respectively.

When tubes incorporating a decimal point are used, it is necessary to employ an additional on/off switch together with a current-limiting resistor for glow equalisation. The additional circuit is illustrated in Figure 13. If, whilst the decimal point is operative, the numeral is switched off, the current to the decimal point will be excessive unless adequate additional current limiting resistance is provided.

Pre-bias

Some switching circuits, particularly those using electronic rather than mechanical switches, require all indicator tube cathodes to be permanently connected in circuit.

In Figure 6 the selector switch is really representative of transistors, thyristors or trigger tubes.

To register the glow on one cathode at a time, such circuitry must arrange for the effective standing bias on all other cathodes to be within specified limits. A bias of +80V relative to the conducting cathode is recommended.

However, values down to 60V or even 50V may be used provided that :

(a) at all times one cathode is conducting

(b) a degree of background haze is tolerable

(c) the tube is not working so close to the minimum current that the required cathode is unduly deprived of current. (At low bias values the non-glowing cathodes rob the selected cathode of positive ion current.) See Figure 15.

The maximum safe value of pre-bias voltage in just below that of the current reversal voltage, namely, 110V. If the cathodes are above reversal potential, they collect electrons and act as auxiliary anodes : unless the pre-bias circuit impedence is very high there is a risk of the cathode current becoming excessive.

It is common practice to use n-p-n transistors to switch the cathode potentials, one at a time, to that of the negative line. In this case, the pre-bias on other cathodes will be given by the intercept of the forward breakdown characteristic with the indicator probe characteristic, as shown in Figure 16. Thus the minimum pre-bias potential determines the forward breakdown voltage rating required of the transistor.

Fig. 13

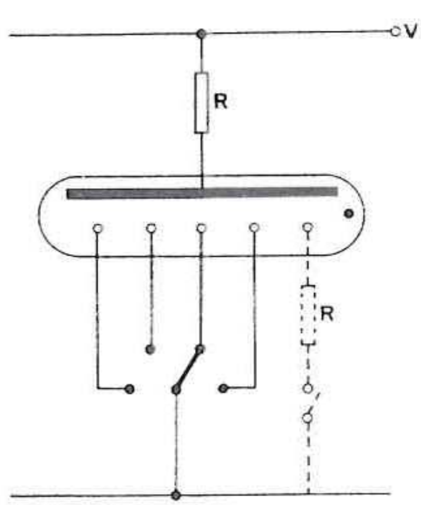


Fig. 14

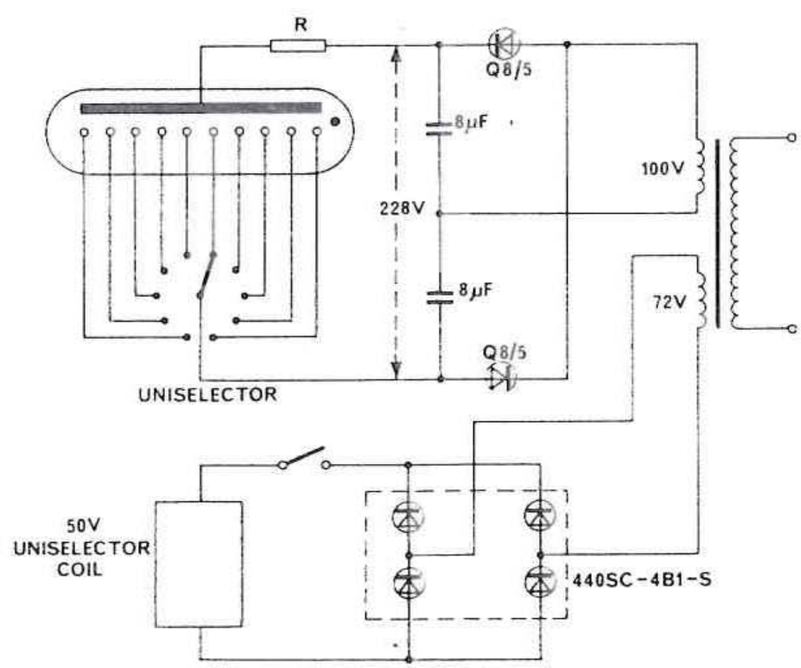


Fig. 15

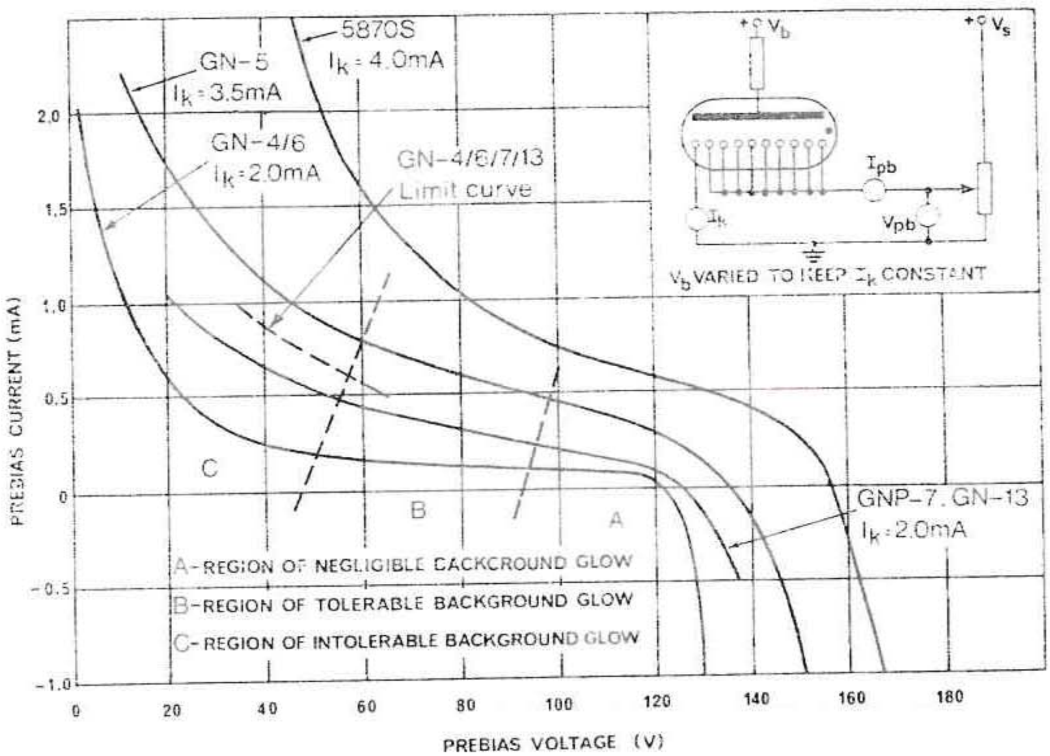
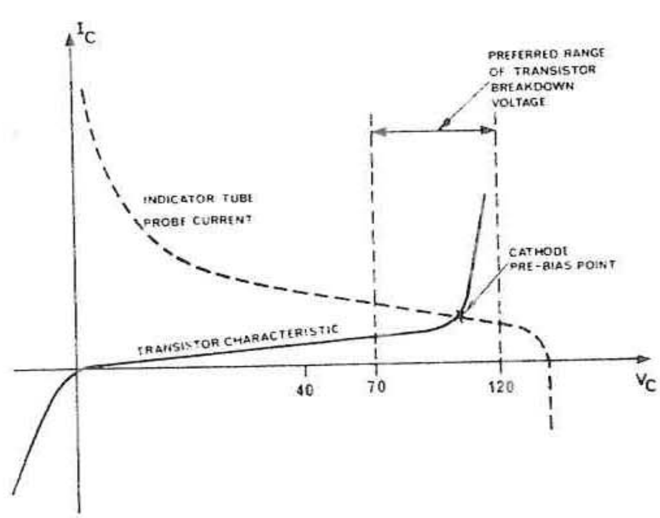

5870S
I_k = 4.0mA
GN-5
I_k = 3.5mA
GN-4/6
I_k = 2.0mA
GN-4/6/7/13
Limit curve
V_b
V_s
I_{pb}
I_k
V_{pb}
V_b VARIED TO KEEP I_k CONSTANT
GNP-7, GN-13
I_k = 2.0mA
C
B
A
A-REGION OF NEGLIGIBLE BACKGROUND GLOW
B-REGION OF TOLERABLE BACKGROUND GLOW
C-REGION OF INTOLERABLE BACKGROUND GLOW
PREBIAS CURRENT (mA)
PREBIAS VOLTAGE (V)

Fig. 16


I_C
PREFERRED RANGE OF TRANSISTOR BREAKDOWN VOLTAGE
INDICATOR TUBE PROBE CURRENT
CATHODE PRE-BIAS POINT
TRANSISTOR CHARACTERISTIC
40
70
120
V_C

Transistor Switching

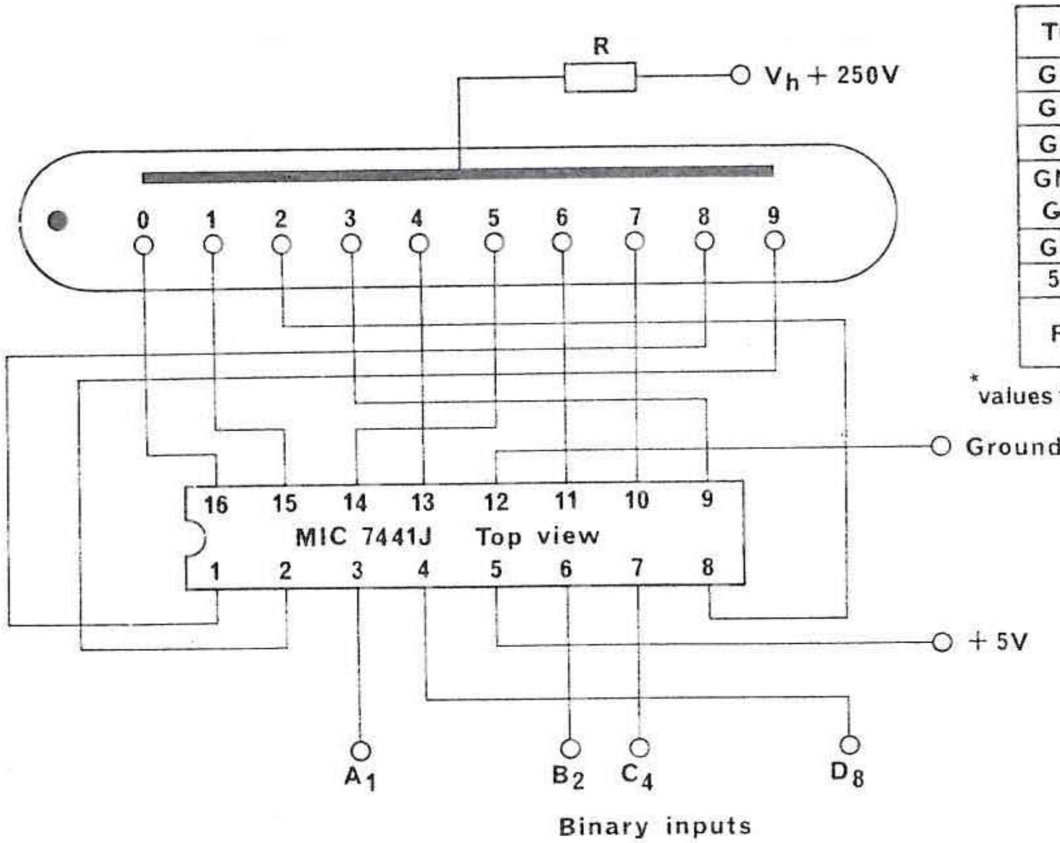
Since common-emitter connected transistors amplify both voltage and current, their use as drivers for indicator tubes makes it possible to inter-face with low voltage, low current integrated circuits. It is possible to obtain the drive transistors incorporated in an integrated circuit as illustrated in Figure 17. Such a TTL circuit decodes the output of a four-stage binary counter and connects the appropriate cathode of the indicator tube to "ground".

A decoder/driver circuit using ten separate drive transistors BSY 79 in biquinary connection and two DTL integrated circuits is also given in ITT Application Note 6251/287E, and a modification of this circuit to cope with high peak currents in time shared numeral indicator tube operation is given in Figure 21.

Associated Logic Circuits

It is beyond the scope of this booklet to detail the circuitry associated with many instruments in which numeral indicator tubes are used as the read-out devices : the following items are restricted to simple counters and to time-sharing circuits which permit several numeral indicator tubes to be operated by the same driver circuit. For simplicity the circuits are shown as wiring diagrams—details of the integrated circuits quoted are contained in ITT publication 6000/303E.

Fig. 17.—Decoder/Driver and Display



Tube	*R (kΩ)
GN-4	56
GN-5	33
GN-6	68
GNP-7 GN-13	56
GN-9	68
5870S	36
For V_h = 250V	

*values for non-pulsed operation

Counter Circuits

IC decade counters commonly use binary counting with feedback circuitry in each set of 4 binaries to effect recycling after 10 rather than 16 counts. Such a binary-coded-decimal (BCD) counter is available in a single TTL package (Figure 18) or in 3DTL packages (Figure 19). These circuits may be cascaded to provide counters with multi-decade displays.

Fig. 18.—TTL Binary-coded-decimal Counter (1-2-4-8 code)

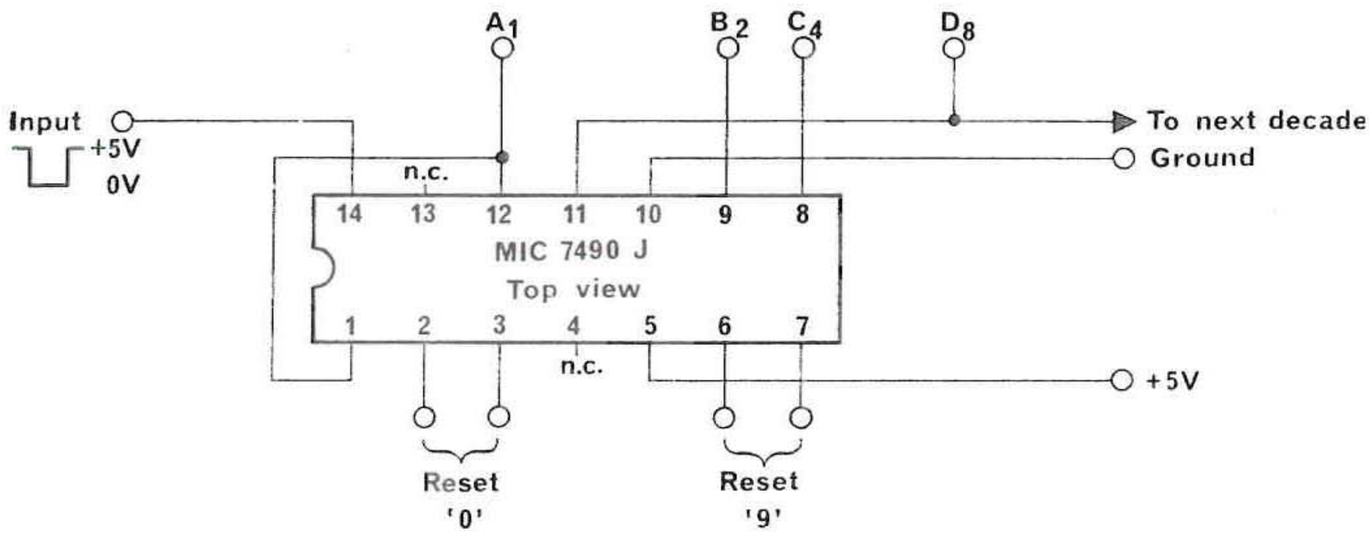
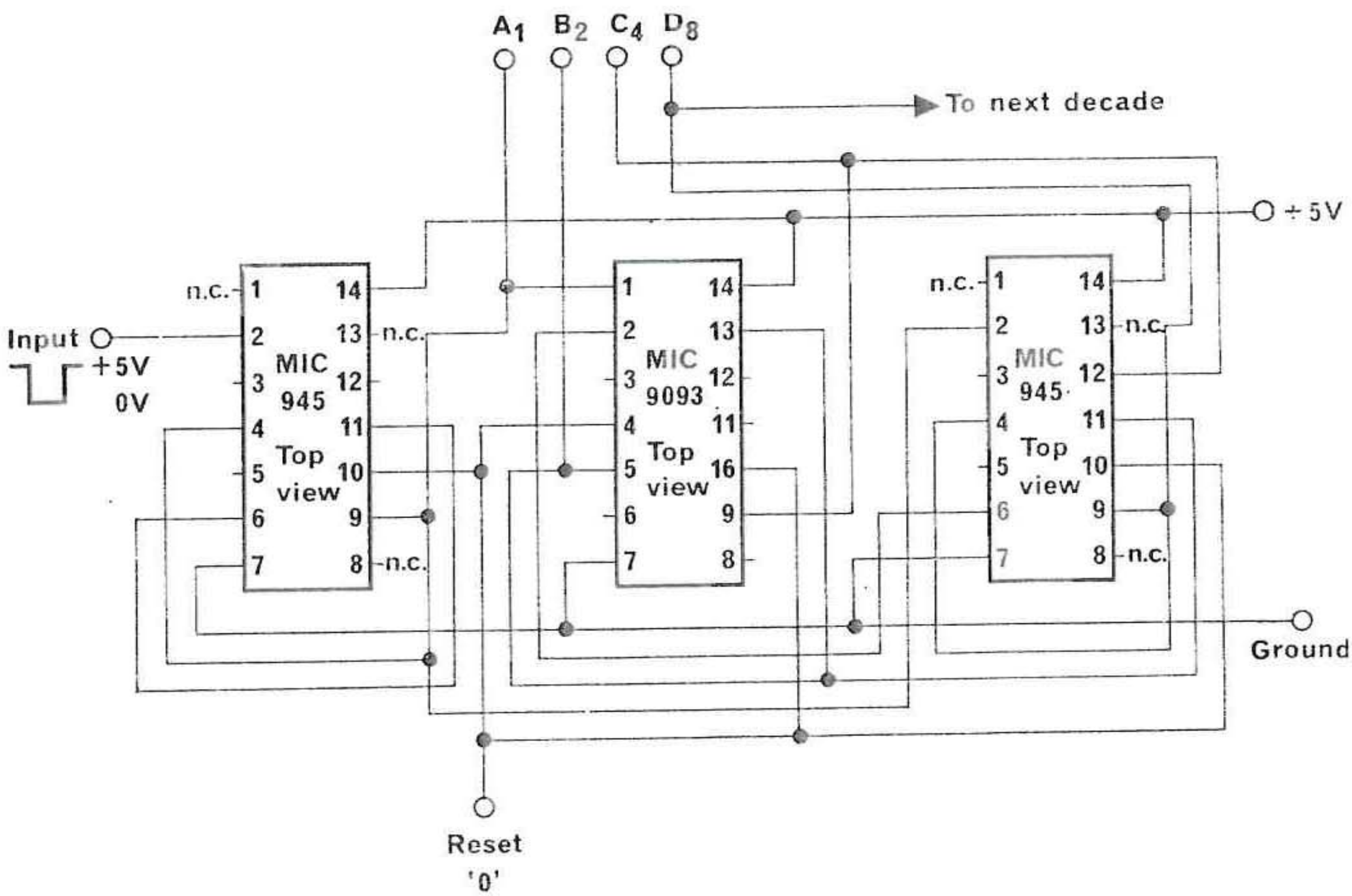


Fig. 19.—Alternative Binary-coded-decimal using DTL (1-2-4-8 code)



Buffer Store

Sometimes a display is required to hold a reading for a period until new information needs to be sampled. Such a circuit is given in Application Report 6251/287E.

Time-Sharing Displays

By sequentially pulsing the anodes of several numeral indicator tubes, only one driver unit is needed for a row of tubes but the resulting saving is partly offset by the extra circuits for anode strobing. The block diagram (Figure 20) shows the relationship with other circuits and indicates the principal components quoted in these examples.

As the brightness of the display is proportional to average current, it should be noted that when time-sharing is used higher current levels are required during pulsed periods than when operating under d.c. conditions.

The detailed design of the shift register is dependent upon specific equipment requirements. For the eight numeral indicator tube combination described below a four-channel eight-bit shift register comprising four MIC7491J packages with three MIC7400J recirculating gates could be used. The four MIC7491J devices provide the complementary outputs $\bar{A}$ $\bar{B}$ $\bar{C}$ $\bar{D}$ in addition to A B C D, all of which are required by the decoder shown in Figure 21. The information supplied to the tube cathodes by this decoder is synchronised with the numeral indicator tube anode selection by driving both with common clock pulses of p.r.f. chosen between noticeable flicker rate and about 10kHz. Essentially the p.r.f. chosen should allow at least the minimum pulse duration of 100μs specified for the numeral indicator tubes.

Fig. 20.—Time-sharing Circuit

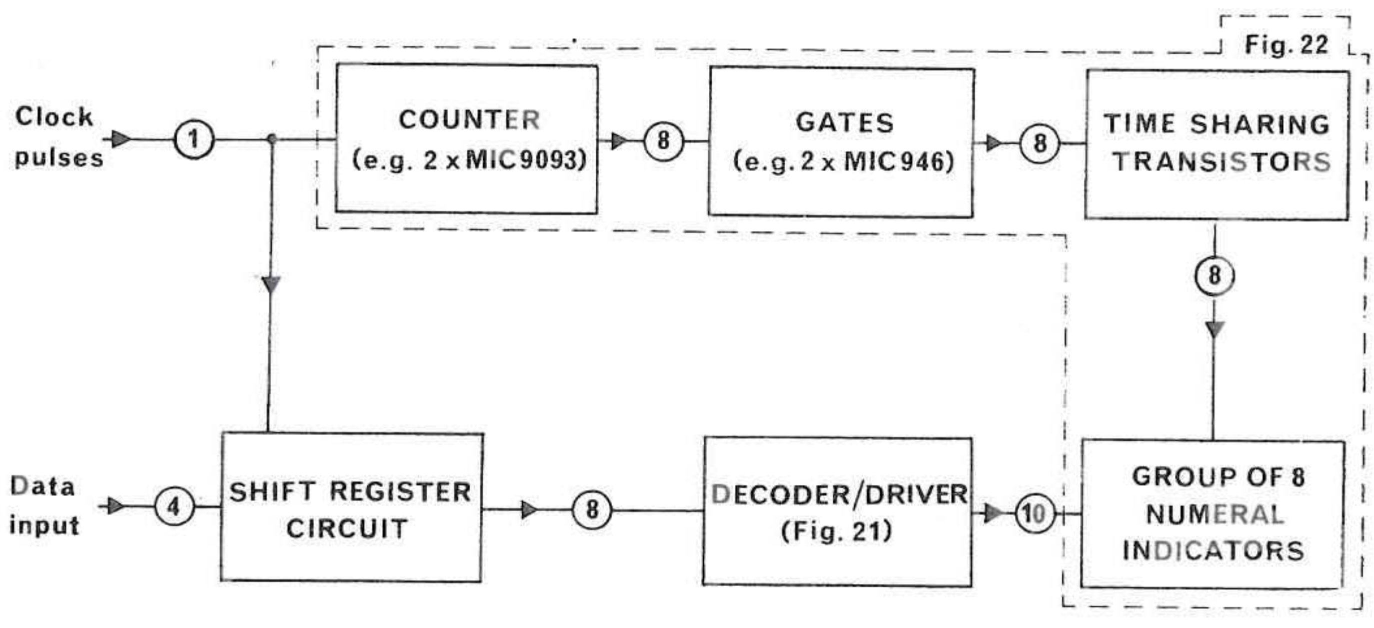


Fig. 21.—Decoder for Time-sharing System (Cathode drive)

This unit is common to all the numeral indicator tubes and is capable of driving up to sixteen tubes (but in the example under consideration the number of tubes is eight). The tubes have like cathodes common-connected.

Ten separate cathode driver n-p-n transistors are used because the TTL driver MIC7441J of Figure 17 has inadequate current rating to drive eight numeral indicator tubes.

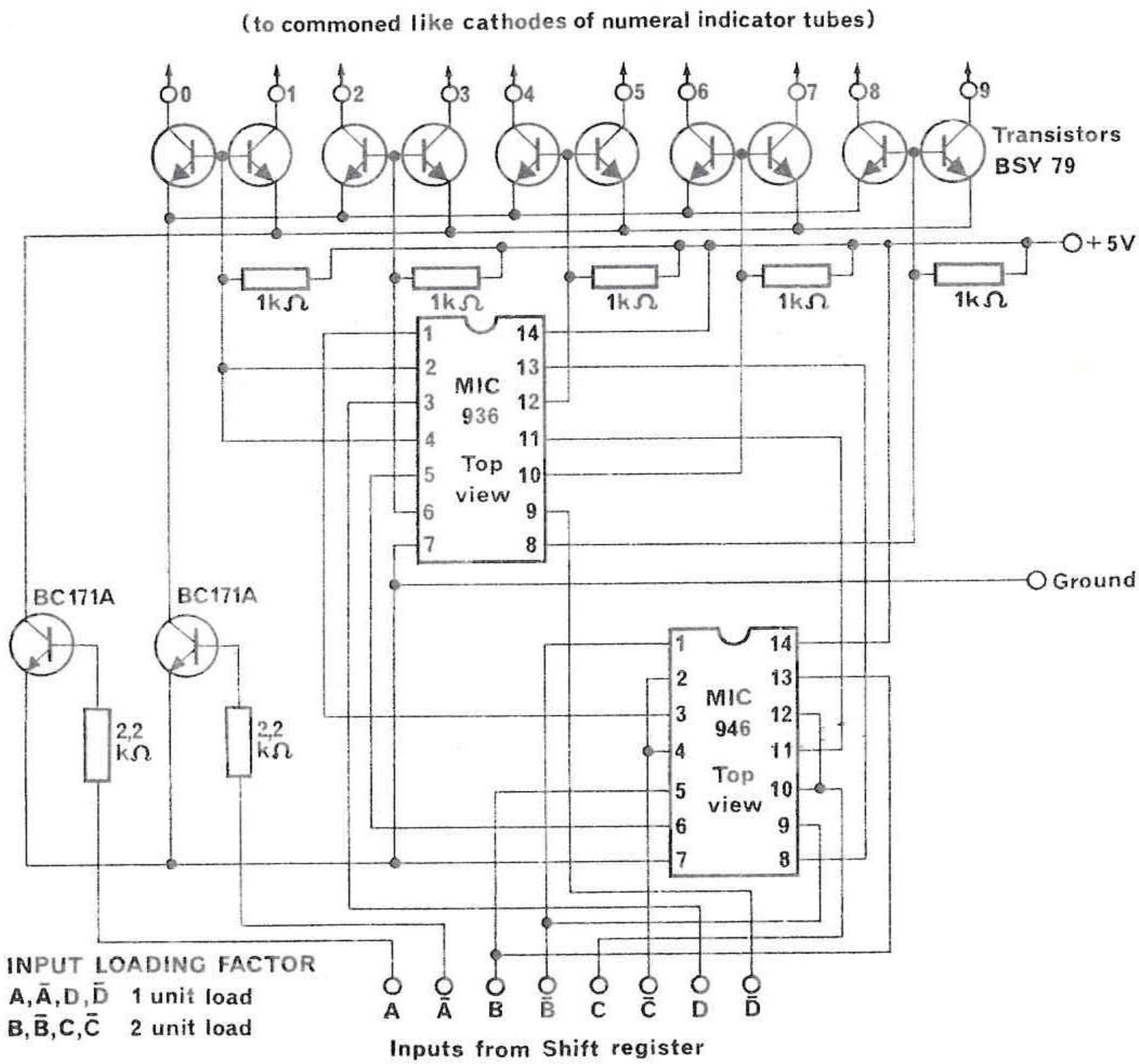
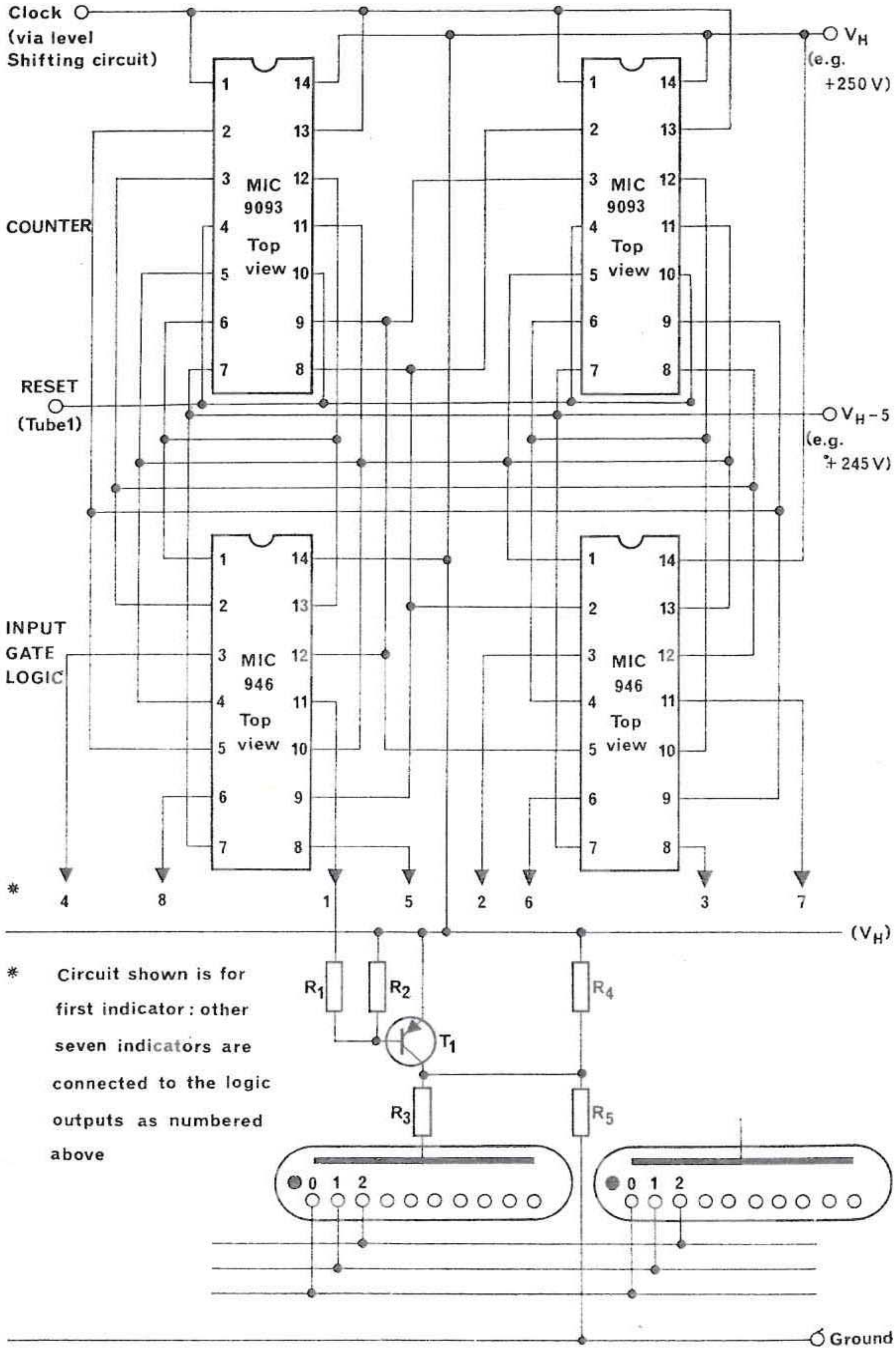


Fig. 22.—Time-sharing Circuit (Anode drive)



Counter/Gates/Time-sharing Transistors (Figure 22)

Fig. 22

The numeral indicator tube anode drive transistors (T_1, etc.) are high voltage types and are p-n-p to allow a drive signal to be applied between the bases of these transistors and the h.t. rail. The voltage rating of these transistors can be limited to 100V less than h.t. by potential divider resistors R4, R5 of relatively high value. Resistor R2 is required to avoid limiting the breakdown voltage of transistor T1, its value being dependent upon transistor type and the supply voltage; typically R2 is several hundreds of ohms. The resistance of R1 must be low enough to provide adequate base-drive for T1 but not less than 560Ω if MIC 946 DTL gates are used. In turn, these gates are driven by a counter which must contain a bistable with access to both outputs for each pair of indicator tubes; thus MIC 945 or MIC 9093 may be used as required.

NOTE. ITT Manufacturing Services at Cefndy Road, Rhyl, are available to manufacture counting and decoding modules to suit customers' specific applications.

The undermentioned applications notes are available on request from ITT Semiconductors Ltd., Footscray, Sidcup, Kent, England.

6251/287E	Binary to decimal decoder.
6251/345E	The MIC 7400 series of TTL digital integrated logic circuits.
6251/347E	Power supply considerations.
6251/351E	Fundamental aspects of logic design.

ITT Components are available from:

or directly from:

ITT Components Group Europe
Valve Product Division.
Brixham Road,
PAIGNTON, TQ4 7BE, Devon.
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