Timer Counter TC9.

Instruction Manual

ADVANCE

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This timer counter is a six digit instrument capable of measuring frequencies up to at least 32MHz at 10mV with a resolution of 0.1Hz. For higher resolution at frequencies up to 100kHz, a multiple period measurement facility is provided.

In addition this instrument, in which integrated circuits are widely used for maximum reliability and space utilisation, will measure time intervals with a resolution down to 1μS

This instrument may also be used for the counting of regular or random events during accurate time intervals adjustable in decade steps over the range 1mS to 10S, or during intervals determined manually by push buttons, or by external electrical signals

The six display tubes used on the instrument are of a new type which provides an extremely bright clear in-line reading and enable the instrument to be used in adverse lighting conditions.

A three position switched input attenuator is provided, with an impedance of 1MΩ, enabling the instrument to be used with standard oscilloscope probes.

DISPLAY
Six in-line neon numerical indicators with decimal points for frequency and multiple period

FREQUENCY MEASUREMENTS
2Hz to 32MHz via input A with gate time of 1mS to 10S in decade steps. Decimal point automatically positioned to indicate kHz.

TIME MEASUREMENT
Timing units from 1μS to 10S in decade steps. Start and stop inputs can be A to A (equivalent to single period), B to B or B to C or by push button.

MULTIPLE PERIOD
From 10 to 10^6 periods in decade steps within frequency range 2Hz to 100kHz.

COUNT
2Hz to 32MHz via input A with start and stop controls via inputs B to B or B to C, or by push button.

INPUT A
SENSITIVITY Three position attenuator providing 10mV, 100mV and 1V RMS sensitivities, from 2Hz to 32MHz.
INPUT IMPEDANCE 1MΩ/approx. 18pf, suitable for use with oscilloscope type probes.
In 10mV position, protective limiting reduces input impedance to 200kΩ/approx. 120pf, with signals over 1V RMS.
MAXIMUM INPUT

Up to 20kHz	250V DC, 250V AC RMS
Over 20kHz	30V AC RMS in 100mV and 1V position
	3V AC RMS in 10mV position.

INPUTS B AND C
SENSITIVITY 1V peak negative going, fall time between 1nS and 100nS
MAXIMUM INPUT $\pm$3V peak.
Inputs B and C operative on time and count functions only

FREQUENCY STANDARD
INTERNAL 1MHz crystal oscillator, oven controlled at +65°C. Set to 1 in 10^6 at +25°C. Stability $\pm$5 in 10^6 from 0°C to +50°C after one hour warm-up period.
EXTERNAL Via rea panel jack socket, coupled through 400V pk. working blocking capacitor.

SENSITIVITY

Sine Wave 0.5V to 10V RMS within frequency range 10kHz to 2MHz

Pulse 1V to 20V p.t.p. within frequency range 10Hz to 2MHz

The negative duration must not be greater than ten times the positive duration.

CHECK FACILITY

The 1MHz Standard is counted for the gate time selected.

DISPLAY TIME

Continuously adjustable from 0.1S to 4S, or infinite.

RESET

INTERNAL Automatically at end of display period.

EXTERNAL By push-button or external contact closure to ground. Open circuit voltage +18V maximum. Short circuit current limited to 15mA peak.

TIME UNITS OUTPUT

Pulses are available at rear panel socket derived from frequency standard via decade dividers. Time units of 1μS to 10S are selected by time units switch. Amplitude approximately 3V p.t.p. from non-linear high impedance A separate 1MHz output is also provided, via a further rear panel socket of approximately 2V p.t.p. from high impedance and is available at all counter settings.

DATA OUTPUT

Display data is available at pins on the printed circuit board. Format is 8421 BCD positive going, negative true from high impedance.

POWER SUPPLY

100 to 125V, 200 to 250V, 45 to 65Hz, 30VA

OPERATING TEMPERATURE RANGE

0 to+50°C

ACCESSORIES SUPPLIED

One 50Ω BNC/BNC Connector PL43

One 50Ω BNC/Clips Connector PL44

One miniature Jack Plug Part No. 2727

Three 4 mm Plugs Part No. 1244

One Instruction Manual Part No. 25883

DIMENSIONS AND WEIGHT

11" (28cm) wide, 5¾" (15cm) high, 9⁷/8" (25cm) deep overall

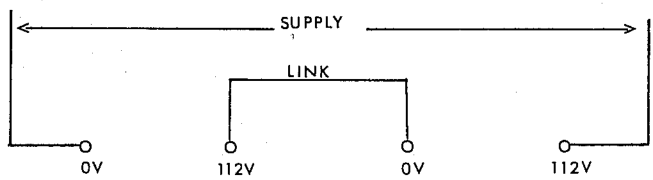
10½lb. (4.8kg)

3.1 PRELIMINARY

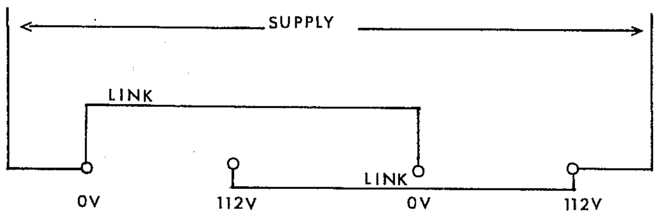
The instrument is normally despatched from the factory for use with AC supply voltages within the range 200V to 250V. To operate from AC supply voltages between 100V and 125V proceed as follows:-

Four taps are provided on the side of the supply transformer T1 nearest the top of the instrument; these are marked 0, 112V-0-112V and enable the primary windings to be connected either in series (for 200V to 250V operation) or in parallel (for 100V to 125V operation).

The instrument is normally supplied for 200V to 250V operation with the windings connected in series, i.e. thus:-



To connect for 100V to 125V operation, remove the link and parallel the windings thus:-



Note that no connections to the other tags on the transformer must be made or disturbed.

When the instrument is despatched it is normally fitted with 2.5 amp fuses in the fuse holders on the rear panel which is suitable for 200-250V operation. However 4.0 amp fuses should be fitted for 100-125V operation to prevent the fuses from being blown with the switch-on surge. The supply on - off switch is operated by the function switch, and when the instrument is connected to the supply and switched to the required function the neon indicator tubes will be illuminated.

3.2 INTERNAL STANDARD

Although the crystal oven begins to cycle on and off within a few minutes of switching on the counter, the maximum standard accuracy is only achieved after a period of one hour. At an ambient temperature of 25°C an accuracy of 3 parts in 10^6 is obtained typically within 20 minutes.

3.3 DISPLAY AND RESET

When the SAMPLE RATE control is switched to the HOLD position reset may be actuated manually by the push button or by a closed contact to ground at the external reset socket. Repetitive readings are obtained by turning the control clockwise, the length of time for which a reading is displayed depends on the setting of this control and may be varied from at least four seconds to less than 0.1 seconds when the control is fully clockwise, at the maximum sample rate.

The use of longer display times is advisable with measurements having a gate time longer than about 0.01 sec. since a very rapid sampling rate (short display time) makes it difficult to observe the steady display during the period when the gate is closed.

3.4 FREQUENCY MEASUREMENT

The frequency of signals of at least 10mV RMS and not greater than 250 volts up to 20kHz and not greater than 3 volts above 20kHz from 2Hz to 32MHz can be measured, using the BNC input socket A. The input attenuator should be used with larger signals as appropriate, in the 100mV or 1V position. This will also enable inputs up to 30 volts, above 20kHz, to be measured. The input impedance of 1MΩ and 18pF enables a normal oscilloscope probe to be used.

The GATE TIMES switch shows five gate times: 10^{-3}, 10^{-2}, 10^{-1}, 1, and 10 seconds. In each case the display indicates kHz with an automatically positioned decimal point. The longer gate times can be used to obtain a greater number of digits and thus greater accuracy. For greater accuracy below about 100kHz it is advisable to select MULTIPLE PERIODS.

A greater number of digits than six can be obtained by taking two measurements, one measurement to obtain the most significant digits, and another to obtain further digits, whilst overspilling the most significant ones by using longer gate times.

NOTE that an external standard is necessary to achieve accuracies of more than 1 in 10^6 .

3.5 PERIOD MEASUREMENT
(a) TIME A-A for single period measurements
To obtain an accurate determination of lower frequencies it is better to measure the period of the signal, that is, the time elapsing between two consecutive negative going signals exceeding the triggering threshold. This is performed when the selector switch is set to TIME A-A.

The setting of the TIME UNITS switch determines the units of the display and it is necessary to take the reciprocal to obtain the frequency. For example using micro seconds units (TIME UNITS 10^{-6} secs) a reading of 200, 000 $\pm 1 \mu S$ gives a frequency of 5Hz $\pm 0.0005\%$.

However any period measurement suffers from a trigger point error due to hum and noise on the signal, causing the trigger point at which measurements are made to jitter in time. Use of maximum sensitivity may reduce this error. However very noisy signals may cause spurious triggering, in which case the signal should be attenuated. When using the 100mV or 10mV positions particularly, care should be taken not to pick up spurious signals. (with unscreened leads for example)

(b) MULTIPLE PERIOD
The time indicated on the counter is always in millisecond units, and is the time elapsing between the first positive going signal to trigger the counter and a selected subsequent positive signal.

The selection of the latter signal is made according to the NUMBER

OF PERIODS selected, which may be any power of ten from 10 to a million.

On MULTIPLE PERIODS x 10^4 the accuracy achieved,for example at 50kHz is $\pm 0.0005\%$, neglecting any trigger point error and accuracy increases progressively with greater numbers of periods and with lower frequencies.

3.6 TIME MEASUREMENTS
In addition to the TIME A-A function, time measurements can be made in three modes.

(a) TIME B-B
The TIME UNITS selected are counted between the first and second negative going pulses at the B input socket, after a reset has been applied. Subsequent pulses have no effect, until reset is again applied. The pulses, which are specified in SECTION 2, must not exceed 3V or the instrument may be damaged.

(b) TIME B-C
In this position of the FUNCTION SWITCH, the selected TIME UNITS are counted between the application of a negative going pulse at the B input and a subsequent negative going pulse at the C input. The counter does not respond to any pulse at the C input before the pulse at B or any subsequent pulses before the next reset is applied.

Both the B and C inputs may be activated by a closed contact to ground if a 150KΩ resistor is connected between the input and ground (i.e. across the contact) and a 470KΩ resistor from the input to the RESET socket, which provides a suitable voltage, approximately 16V via 220KΩ. Contact bounce may be suppressed by a capacitor of the order of 0.01μF connected across the contacts.

(c) MANUAL
In the TIME and COUNT Positions (see 3.7) the manual START and STOP push buttons may be used to control the gate. Reset must be applied before the buttons are operated again.

3.7 COUNTING
This function is similar to the TIME B-B and B-C functions except that the number of cycles of any signal at the A input

socket is counted between start and stop signals. These start and stop signals may be applied in any of the ways detailed for the time measurement.

3.8 CHECK

This facility enables the counting and time base decades to be checked. When the function switch is in this position the standard frequency is counted for a time selected by the time units switch. In the 1 or 10 second gate position the counter should display 000000 $\pm$1 count (i.e. 999999, 000000 or 000001). The SAMPLE RATE control should be set anticlockwise to enable the display to be seen. When the instrument is first switched on it may not count correctly until a reset pulse is applied, since the decades may not start at a zero count state.

NOTE. Check that the EXT. STANDARD jack plug has been removed, since this cuts off the internal standard.

3.9 REAR PANEL SOCKETS

(a) EXTERNAL STANDARD

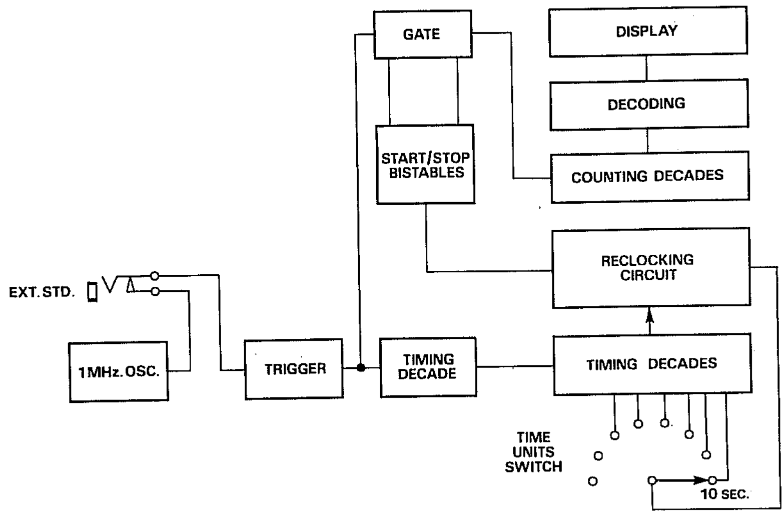
This input can be used to increase the accuracy, or change the scale of measurements. Inserting a jack in this socket automatically disconnects the internal 1MHz standard. Inputs should be as specified in SECTION 2; with positive pulse inputs, the mark-space ratio should not be less than 10 to 1.

(b) 1MHz OUTPUT

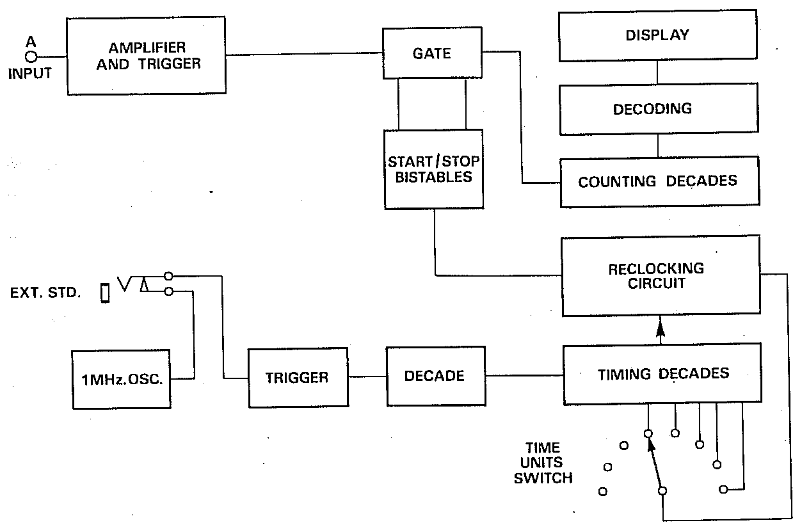
Pulses are available from the internal standard of 2V pk-pk approximately, irrespective of the various control settings.

(c) TIME UNITS OUTPUT

These pulses of 3V pk-pk can be selected by the TIME UNITS switch to occur at repetition rates in decade steps from 1μ S to 10 secs. They are not available in the multiple period and count functions, and the SAMPLE RATE control should be set to HOLD to prevent irregularity due to reset.

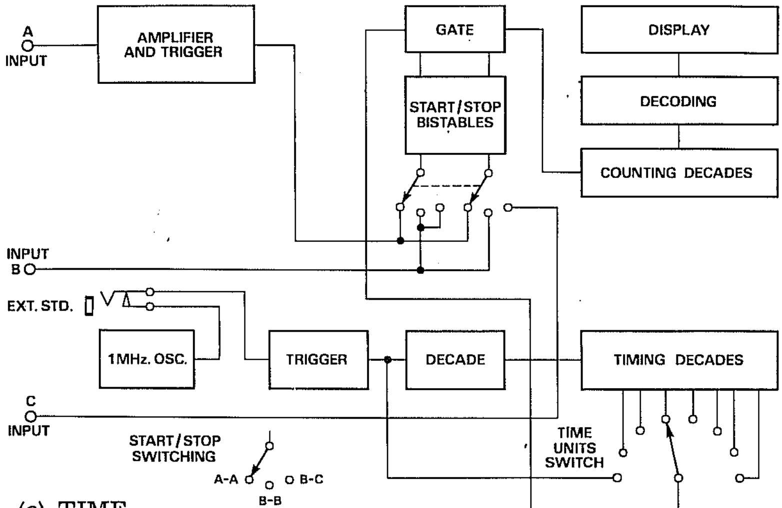


(a) CHECK

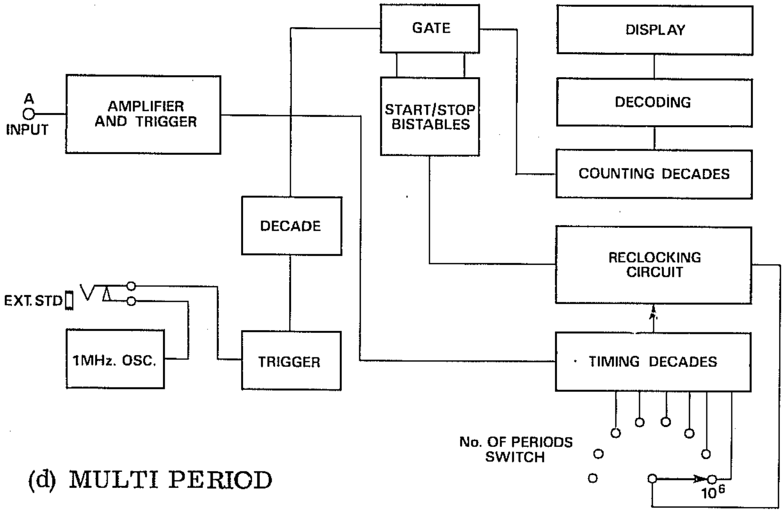


(b) FREQUENCY

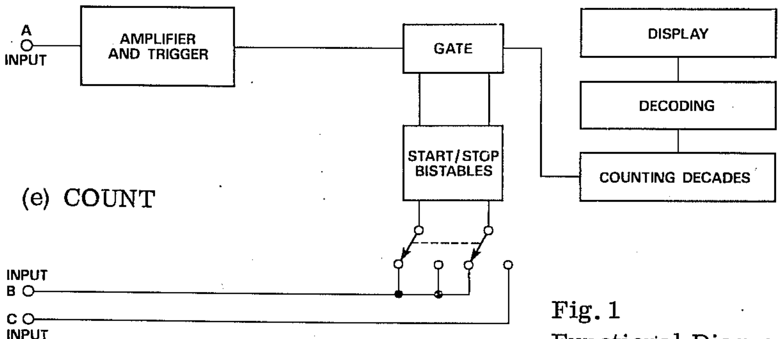
Fig. 1 Functional Diagrams



(c) TIME



(d) MULTI PERIOD



(e) COUNT

Fig. 1
Functional Diagrams

4.1 GENERAL

The circuits of the instrument fall into three main sections, the counting decades and display, the timebase, and the input amplifier. A large part of the circuitry consists of integrated circuits and only the function of these will be described and not their internal circuitry.

Block diagrams of the interconnection of the various circuits for different functions are to be found at the end of section 5, Fig. 1.

4.2 INPUT CIRCUIT (Fig. 2)

The input signal at socket A is amplified by the input amplifier and converted to square waves by the trigger circuit.

The input signal is fed through the switched attenuator to the high impedance field effect transistor stage VT1, which is biased by a constant current stage VT2. Protection against excessive negative signals is given by MR1 and large positive signals are limited by VT1 itself together with R4 and R5. The signal is coupled by the emitter follower stage VT3 to the three stage transistor amplifier VT4, VT5 and VT6. DC feedback over these three transistors stabilises their operating bias. Capacitors C17, 20 and C21 maintain a level response at high frequencies.

The trigger circuit VT7 and VT8 is a bistable type and VT9 is used to drive into subsequent circuitry without loading the bistable excessively.

4.3 COUNTING AND DISPLAY CIRCUITS (Fig. 4)

(a) START-STOP GATE

The pulses which are to be counted are fed via amplifier VT1 and differentiated by C2/R3.

The transistors VT2, VT3 and VT4, form a gate which is controlled by the two bistable circuits of IC1 which operate as follows:- Initially, after reset, the two '0' outputs, are at the logic '0' level which is 'high' and this output from the 'start' bistable therefore switches VT4 on and closes the gate (the 'start' bistable is the one with the clock 'T' input labelled START).

A negative going pulse at the clock input 'T' of the start bistable causes it to toggle since there is a low (1) level on the clear 'C' input, but the high '0' level on the set 'S' input prevents any further action by this bistable, until it is reset. When this bistable has toggled it removes the bias from VT4 and opens the gate.

Since initially the 'stop' bistable has high '0' levels on both inputs 'S' and 'C', it cannot toggle until after the start bistable has toggled and changed the 'C' input to a low '1' level. Then a negative going pulse on the stop bistable clock input 'T' will cause it to toggle, the '0' high level on the set 'S' input prevents any further action until reset is applied. When the Stop bistable has toggled, it applies bias to VT3 and closes the gate.

While the gate is open, pulses can pass to the drive stage VT5.

(b) HIGH FREQUENCY DECADE
Transistors VT6 and VT7 form a bistable which divides the input pulse frequency by two. VT10, 11; VT12, 13 and VT14, 15 also form conventional diode steered bistables, with speed up diodes (e.g. MR2, MR3) and capacitors, with a gate VT8 and VT9 to give division by five. The circuit functions as follows:-

Initially after reset, transistors VT11, 13 and 14 are conducting (bottomed) VT10, 12, and 15 are therefore cut off. Since VT14 is bottomed it does not switch on VT9, so that as VT7 toggles from the initial cut off state to which it is reset, the first 4 pulses pass through to the bistable VT10 and VT11. This bistable divides the signal by two and the output from VT11 is coupled to the bistable VT12 and 13 which divides by a further factor of two. At the fourth pulse from VT7 therefore, VT14 and 15 toggle and the gate VT8, 9 is closed. The next pulse from VT6 however, causes the bistable VT14, 15 to toggle again and the gate is therefore open again. Outputs from VT7, 10, 12 and 15 provide a binary coded decimal (BCD) output.

TABLE 4.1 DECADE COUNTING where '1' indicates the bottomed state and '0' the cut off state.

Input Pulse No	VT7 BCD '1'	VT10 BCD '2'	VT12 BCD '4'	VT15 BCD '8'
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1
10	0	0	0	0
11	1	0	0	0
12	0	1	0	0
		etc		

(c) INTEGRATED DECADES AND DISPLAY
The BCD outputs from the high frequency decade are fed to the integrated decoding and indicator driving package IC7 and additionally, the positive going edge of the BCD '8' output drives an integrated circuit decade IC2. The BCD '8' output of IC2 drives IC3 and so on, to IC6. Each integrated decade has an associated decoding and read out package to drive the numerical indicator tube. The decoding IC's convert the BCD input to decimal form and 'turn on' the appropriate output connection which causes the neon indicator tube to display the appropriate digit. Decimal point switching is carried out by the function and time unit switches for frequency and multiple period measurements.

(d) RESET PULSE GENERATOR
The reset circuit which resets all decades to zero at the end of the display period functions as follows:-

When the sample rate control is switched from the 'hold' position, a charging current can flow through it into C33, after a stop pulse has triggered the stop bistable IC1 and cut off VT19.
The charging rate is determined by the setting of the sample rate potentiometer. As C33 charges it switches on VT18 and causes

VT20 to cease conducting. VT20 is directly coupled to VT21 and the switching action regenerates through R64 so that a positive reset pulse occurs on the reset line from the collector of VT21. VT22 acts as a buffer to supply the reset pulse to the integrated circuits.

The reset pulse resets the 'O' output of the stop bistable of IC1 to the 'high' state and bottoms VT19 which therefore discharges C33 through R59, and C32 charges through R61 and R64 giving a reset pulse length of approximately 5mS.

The circuit of VT17 enables manual reset to be applied.

4.4 TIMEBASE AND POWER CIRCUITS (Fig. 3)

(a) 1MHz OSCILLATOR
Crystal XL1, VT8 and VT9 form the oscillator circuit, positive feedback occuring between the emitter of VT8 and the emitter of VT9, through XL1.

At the series resonant frequency of the crystal therefore, when its impedance is lowest the positive feedback is greatest and oscillation takes place.

The basic resonant frequency of the crystal is slightly below 1MHz and the series capacitors can be adjusted to raise the frequency to exactly 1MHz.

VT10 is an emitter follower stage which only lightly loads the oscillator stage. The output from VT10 is fed via the EXTERNAL STANDARD jack socket to the trigger circuit VT11, VT12, which shapes the 1MHz, or the external standard frequency, into pulses suitable for driving the timebase.

(b) TIMEBASE (see Fig. 3)
The timebase consists of seven integrated circuit decades which divide the frequency down in stages of ten from 1MHz to 10 seconds. The connection from the first to second decades is made via the function switch so that the decades IC2-IC7 may be used to divide the input frequency in the multiple period function.

The circuitry comprised of IC8 and IC9 is used to re-clock the timebase to eliminate propogation errors when deriving start and stop pulses for the counter gate. The start and stop pulses are timed from the BCD '1' output from the second decade IC2 as follows:

Reset is applied to VT7 which clamps the output of one side of the bistable formed by the interconnection of two gate circuits in IC9.

The first positive going edge from the BCD'1' output of IC2 is amplified and differentiated by part of IC8 and appears as a positive going pulse at the upper gate circuit of IC9, pin 3, and causes it to toggle. The negative going output from the bistable is used as the start pulse.

The selected time units, switched by the TIME UNITS switch from a decade output are amplified and differentiated by the remaining circuitry of IC8 and positive going pulses are fed to the lower gate of the bistable IC9. The first positive going edge occurs after a complete count of 10 by the appropriate decade and this resets the bistable so that the next positive going '1' output from IC2 can cause the bistable to toggle and give a negative stop pulse.

These positive going '1' pulses are therefore gated by the required decade output to give an exact gate time.

Transistors VT4 and VT5 form a gate which is closed during reset to prevent pulses passing into the decades during the reset period and VT6 inverts the signal so that the trailing edge of the reset pulse does not trigger the decade.

(c) POWER SUPPLIES
VT1 is a series regulator transistor for the main power supply, and is controlled by VT2 and VT3 from the reference zener MR5 to give a constant 5.2 volt supply. The integrated circuits are operated from a 3.8 volts supply obtained from the 5.2volt supply by series silicon diodes MR3 and MR4.

The 200 volt DC rectified output from MR1 supplies the indicator tubes and is decoupled by R2, R3 and C2 together with zener diodes MR6 to give a 20 volts supply with a minimum of ripple, suitable for the input amplifier. A further 16 volt supply is obtained by rectifying and smoothing the crystal oven supply and is used to feed the display timer circuit.

5.1 GENERAL

(a) REMOVAL OF CASE

The top and bottom covers may be taken off by removing the two screws at the rear of the instrument and sliding back the covers. If necessary the side covers can also be slid back when the two rear side trims, each retained by two screws, have been removed. The case should only be removed with the instrument power supply disconnected, to prevent accidental short circuits.

(b) ACCESS TO COMPONENTS

The top (timebase) board of the instrument is hinged for ease of servicing and is retained by two screws at the rear.

The input amplifier screen is secured by four screws and the side cover should be removed to gain access to the upper fixings which are to the side plate.

(c) FUSE REPLACEMENT

In addition to the line supply fuse FS1 on the rear panel (see SECTION 3. 1) there is a fuse in the stabilised supply, rated at 1.0 amp. which is fitted on the right hand side of the upper board.

5.2 OSCILLATOR FREQUENCY ADJUSTMENT

When the instrument is despatched from the factory, the oscillator will have been set for the greatest accuracy at room temperature. Ageing is a characteristic of crystal oscillators and this results in a slow drift of frequency. This slight drift is unpredictable and if the best performance is desired it is advisable to check against a standard frequency at periods of a few months and correct as necessary.

A standard frequency having an accuracy of at least 1 part in 10 million is required such as Advance Off Air Frequency Standard OFS1A, Advance FS2 or a straight receiver tuned to the B B C 200kHz Programme from Droitwich. However the latter method can only be used in the absence of modulation.

If the standard frequency is a multiple or sub multiple of 1MHz it can be displayed together with the 1MHz counter frequency from the rear socket, on an oscilloscope to form a Lissajous figure, or with one frequency viewed on a normal timebase triggered from the other frequency. Use the trimmers C17 (coarse) and C18 (fine) to obtain a stationary display. C19 may require changing if XL1 is changed. Alternatively adjust the trimmers to obtain the correct reading of frequency on a 10 second gate time, with a standard frequency greater than 100KHz.

The fine trimmer, which should be adjusted with the covers on the instrument, is accessible through the side cover at the rear of the left hand side of the instrument. Allow at least one hour for the instrument to warm up to maximum accuracy before carrying out the oscillator adjustment.

5.3 GUIDE TO SERVICING

(a) POWER SUPPLIES AND BIAS VOLTAGES

The voltages measured at various points in the instrument, with function switch on CHECK and SAMPLE RATE set to HOLD are as follows:

TABLE 5.1 OPERATING VOLTAGES

Fig. 3 VT1 emitter	+5.4V at 0.75 amps
Fig. 3 C3	+3.5 to 3.95 volts at 0.45 amps
Fig. 2 VT2 emitter	+2.9V ±20%
Fig. 2 VT4 collector	+2.6V ±20%
Fig. 2 VT5 collector	+3.3V ±20%
Fig. 2 VT6 collector	+3.0V ±20%

Other DC voltages should be within 10% of the values in the circuit diagrams except +200V, +16V supplies and AC voltages which should be ±15%. It is important to ensure that at no time more than +4V is applied to the integrated circuits and if a fault is repaired in the power supply circuits, the link on this board (see Fig. 6) can be removed and a dummy load of 15Ω 2watt resistor connected to ground. The voltage across the resistor should not exceed 4V; the link may then be replaced.

(b) FAULT LOCATION

When repairing the instrument the fault should be localised to a specific section of circuitry, where the faulty component can more readily be located. Table 5.2 gives a suitable procedure. Reference should be made to SECTION 4 Fig. 1 and circuit diagrams.

TABLE 5.2 FAULT LOCATION

Test	Fault	Possible cause
Check supply tapping and supply fuse, switch to CHECK	No display	Failure of 200V supply
	All tubes blurred.	Failure of 5.4V supply (check FS2) or 3.8V supply
Press reset button	Display not zero	Faulty reset circuit
Display resets to zero but does not count, switch to 1μS TIME UNITS and TIME B-B, press RESET and START buttons.	Does not count	Fault in start-stop gate or logic. Fault in 1MHz oscillator, trigger or EXT STD socket. Fault on display board.
Switch to each TIME UNITS position in turn and check that counting occurs when RESET and START Applied.	Does not count with longer TIME UNITS	Faulty decade. Faulty part IC8. Fig. 3 Fault on display board.
Apply suitable input to socket A	Counts on CHECK and TIME B-B, B-C but not other functions.	Fault in input amplifier or trigger
	Counts incorrectly	See next test.
Set Time Units to 1 sec. and TIME B-B. Press RESET and START	Right hand digit does not count from 0-9	Fault in transistor decade or read out package.
As above but 0.1 sec. TIME UNITS	Second digit does not count 0-9	Fault in decade IC2 or read out IC8 Fig. 4.

Test	Fault	Possible cause
etc. up to 1μS		Faulty decade or read out.
Apply known input frequency to socket A measure frequency	Incorrect frequency steady readings	Incorrect triggering in input amplifier. Incorrect gate time - try other positions of TIME UNITS SWITCH to find faulty decade in timebase. Fault in reclocking circuit of timebase. Incorrect standard frequency.
Frequency or Period measurements	Erratic readings	Hum or noise on input signal, or input amplifier. Check for steady output from amplifier trigger circuit. Power supply ripple. Poor grounding or screening of input amp.
	Two digits on display tube.	Incorrect (not BCD) output from decade. Faulty readout package.
	Correct operation on manual RESET but not SAMPLE RATE	Display timer circuit fault.

Faults may also be caused by faulty switches, wiring or joints.

Further fault finding may be carried out by using an oscilloscope.

The 1MHz standard should be traced through the timebase decades, ensuring that they divide by ten, with the SAMPLE RATE control in the HOLD position.

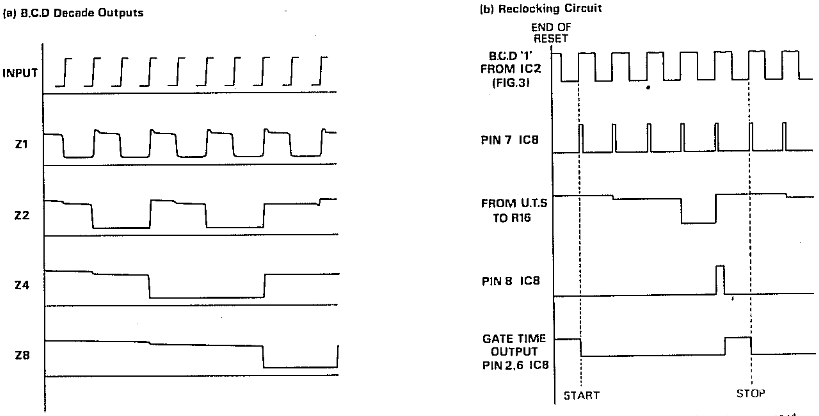
Checking the remaining circuitry is often most easily done using the COUNT function with a normal input signal; after the generation of RESET and application of manual START the counting gate should open and the counting decades may be checked.

Table 5.3 shows typical waveforms observed with a high performance oscilloscope and probe.

NOTE that when ordering spares the circuit reference and board assembly number should always be quoted in addition to the part number and value.

(a) B.C.D Decade Outputs

(b) Reclocking Circuit



Note: The small steps in the waveforms are not significant

Shown with Time Units Switch set to 10^{-4} sec.

6.1 TC9 TIMEBASE AND POWER SUPPLY CIRCUIT 1MHz

Circuit Ref	Value	Description		Part No.
RESISTORS				
R1	330Ω	10%	½W	7878
R2	15K	5%	1W	2051
R3	15K	5%	1W	2051
R4	820Ω	5%	1/8W	1637
R5	330Ω	5%	1/8W	1894
R6	1K	5%	1/8W	384
R7	4.7K	5%	1/8W	386
R8	4.7K	5%	1/8W	386
R9	4.7K	5%	1/8W	386
R10	1.8K	5%	1/8W	310
R11	390Ω	5%	1/8W	2410
R12	560Ω	5%	1/8W	308
R13	3.3K	5%	1/8W	1638
R14	2.7K	5%	1/8W	311
R15	3.3K	5%	1/8W	1638
R16	270Ω	5%	1/8W	2716
R17	2.2K	5%	1/8W	425
R18	5.6K	5%	1/8W	787
R19	1K	5%	1/8W	384
R20	1K	5%	1/8W	384
R21	3.9K	5%	1/8W	312
R22	1K	5%	1/8W	384
R23	1K	5%	1/8W	384
R24	Not fitted			
R25	Not fitted			
R26	10K	5%	1/8W	11503
R27	330Ω	5%	1/8W	1894
R28	4.7K	5%	1/8W	386
R29	470Ω	5%	1/8W	1373
R30	4.7Ω	5%	1/8W	386
R31	10K	5%	1/8W	11503
R32	470Ω	5%	1/8W	1373
R33	1.2K	5%	1/8W	2087
R34	10Ω	5%	1/8W	2259
R35	33Ω	5%	1/8W	2931
R36	6.8K	5%	1/8W	313
R37	33Ω	5%	1/8W	2931

Circuit Ref	Value	Description			Part No.
CAPACITORS					
C1	16μF	Electrolytic	-20% +50%	350V	
C2	30μF		-20% +50%	250V	12189
C3	1000μF		-10% +50%	6.4V	24797
C4	1000μF		-10% +50%	6.4V	24797
C5	.047	Ceramic	+80% -20%	30V	2793
C6	200μF	Electrolytic	-10% +50%	10V	20782
C7	3200μF	Electrolytic	-10% +50%	16V	
C8	18pF	Ceramic	10%	500V	22367
C9	18pF	Ceramic	10%	500V	22367
C10	.05	Ceramic	20%	12V	19657
C11	.05	Ceramic	20%	12V	19657
C12	470p	Ceramic	10%	500V	22383
C13	18p	Ceramic	10%	500V	22367
C14	1500pF	Ceramic	10%	500V	22388
C15	.05μ	Ceramic	20%	12V	19657
C16	.05μ	Ceramic	20%	12V	19657
C17	4-60p	Trimmer			1866
C18	1.5-8p	Trimmer			17998
C19	27p	Ceramic A.O.T.	20%	500V	22369
C20	4700p	Ceramic	25%	500V	22393
C21	Not fitted				
C22	Not fitted				
C23	.047	Polyester	20%	400V	3398
C24	18pF	Ceramic	10%	500V	22367
C25	400μ	Electrolytic	-10% +50%	25V	20784
C26	.05μ	Ceramic	20%	12V	19657
C27	0.1μF	Lemplac		30V	19647

Circuit Ref	Value	Description		Part No.
VT2		Transistor 2N3053		4039
VT3		Transistor 2N930		21548
VT4		Transistor BSX19		22171
VT5		Transistor BSX19		22171
VT6		Transistor BSX19		22171
VT7		Transistor BSX20		22307
VT8		Transistor BSX19		22171
VT9		Transistor BSX19		22171
VT10		Transistor BSX19		22171
VT11		Transistor BSX19		22171
VT12		Transistor BSX19		22171
MR1		Diode BYX10		21251
MR2		Bridge Rectifier	1.5A	19725
MR3		Diode 1N4003		23462
MR4		Diode 1N4003		23462
MR5	4.3V	Diode Zener 5%	400mW	1723
MR6	20V	Diode Zener 5%		19955
MR7		Diode 1544		18970
MR8		Diode MS1H		18806
FS1		Fuse	1A	1254
IC1		Integrated Circuit Decade 6995879		
IC2		Integrated Circuit Decade 6995879		
IC3		Integrated Circuit Decade 6995879		
IC4		Integrated Circuit Decade 6995879		
IC5		Integrated Circuit Decade 6995879		
IC6		Integrated Circuit Decade 6995879		
IC7		Integrated Circuit Decade 6995879		
IC8		Integrated Circuit 5992729		24094

Circuit Ref	Value	Description		Part No.
IC9		Integrated Circuit 5991429		24091
XL1		Crystal 1MHz		22350
FS2		Fuse	1A	1254

6.2 TC9 DISPLAY BOARD

Circuit Ref	Value	Description		Part No.
RESISTORS				
R1	1.2K	5%	1/8W	2087
R2	330Ω	5%	1/8W	1894
R3	4.7K	5%	1/8W	386
R4	330Ω	5%	1/8W	1894
R5	680Ω	5%	1/8W	309
R6	680Ω	5%	1/8W	309
R7	680Ω	5%	1/8W	309
R8	100Ω	5%	1/8W	11504
R9	2.7K	5%	1/8W	311
R10	4.7K	5%	1/8W	386
R11	330Ω	5%	1/8W	1894
R12	2.7K	5%	1/8W	311
R13	2.7K	5%	1/8W	311
R14	330Ω	5%	1/8W	1894
R15	4.7K	5%	1/8W	386
R16	2.7K	5%	1/8W	311
R17	2.7K	5%	1/8W	311
R18	330Ω	5%	1/8W	1894
R19	2.7K	5%	1/8W	311
R20	4.7K	5%	1/8W	386
R21	330Ω	5%	1/8W	1894
R22	2.7K	5%	1/8W	311
R23	2.7K	5%	1/8W	311
R24	330Ω	5%	1/8W	1894
R25	4.7K	5%	1/8W	386
R26	2.7K	5%	1/8W	311
R27	2.7K	5%	1/8W	311
R28	4.7K	5%	1/8W	386
R29	330Ω	5%	1/8W	1894
R30	2.7K	5%	1/8W	311
R31	2.7K	5%	1/8W	311
R32	330Ω	5%	1/8W	1894
R33	4.7K	5%	1/8W	386
R34	2.7K	5%	1/8W	311
R35	2.7K	5%	1/8W	311
R36	4.7K	5%	1/8W	386
R37	2.7K	5%	1/8W	311

Circuit Ref	Value	Description			Part No.
R38	330Ω		5%	1/8W	1894
R39	2.7K		5%	1/8W	311
R40	2.7K		5%	1/8W	311
R41	4.7K		5%	1/8W	386
R42	2.7K		5%	1/8W	311
R43	330Ω		5%	1/8W	1894
R44	3.3K		5%	1/8W	1638
R45	3.3K		5%	1/8W	1638
R46	3.3K		5%	1/8W	1638
R47	3.3K		5%	1/8W	1638
R48	3.3K		5%	1/8W	1638
R49	33K		5%	1/8W	317
R50	33K		5%	1/8W	317
R51	33K		5%	1/8W	317
R52	33K		5%	1/8W	317
R53	33K		5%	1/8W	317
R54	33K		5%	1/8W	317
R55	220K		5%	1/8W	4023
R561	1K		5%	1/8W	384
R57	1K		5%	1/8W	384
R58	1K		5%	1/8W	384
R59	100Ω		5%	1/8W	11504
R60	680Ω		5%	1/8W	309
R61	15K		5%	1/8W	315
R62	2K		5%	1/8W	425
R63	220Ω		5%	1/8W	304
R64	15K		5%	1/8W	315
R65	330Ω		5%	1/8W	1894
R66	330Ω		5%	1/8W	1894
CAPACITORS					
C1	15pF	Ceramic	10%	500V	22366
C2	.05μF		20%	12V	19657
C3	22pF		10%	500V	22368
C4	15pF		10%	500V	22366
C5	15pF		10%	500V	22366
C6	47pF		10%	500V	22372
C7	Not fitted				
C8	Not fitted				
C9	22p	Ceramic	10%	500V	22363

Circuit Ref	Value	Description				Part No.
CAPACITORS (Cont)						
C10	22p		10%	500V		
C11	15p		10%	500V		22366
C12	15p		10%	500V		22366
C13	15p		10%	500V		22366
C14	22p		10%	500V		22368
C15	15p		10%	500V		22366
C16	15p		10%	500V		22366
C17	22p		10%	500V		22368
C18	.05μF		20%	12V		19657
C19	22p		10%	500V		22368
C20	22p		10%	500V		22368
C21	15p		10%	500V		22366
C22	15p		10%	500V		22366
C23	22p		10%	500V		22368
C24	15p		10%	500V		22366
C25	15p		10%	500V		22366
C26	15p		10%	500V		22366
C27	22p		10%	500V		22368
C28	15p		10%	500V		22366
C29	.05μF		20%	12V		19657
C30	10.000pF		25%	250V		22395
C31	0.1μF	+80%	+80% -20%	30V	Lemlac	19647
C32	.22μF		10%	460V		2601
C33	4.7μF		10%	100V		
C34	.05		20%	12V		19657C35
C35	.05		20%	12V		19657
MR1		Diode 1S44				18970
MR2		Diode 1S44				18970
MR3		Diode 1S44				18970
MR4		Diode 1S44				18970
MR5		Diode 1S44				18970
MR6		Diode 1S44				18970
MR7		Diode 1S44				18970
MR8		Diode 1S44				18970
MR9		Diode 1S44				18970
MR10		Diode 1S44				18970
MR11		Diode 1S44				18970

Circuit Ref	Value	Description	Part No.
MR12		Diode 1S44	18970
MR13		Diode 1S44	18970
MR14		Diode 1S44	18970
MR15		Diode 1S44	18970
MR16		Diode 1S44	18970
MR17		Diode 1S44	18970
MR18		Diode 1S44	18970
VT1		Transistor BSX20	23307
VT2		Transistor BSX19	22171
VT3		Transistor BSX19	22171
VT4		Transistor BSX19	22171
VT5		Transistor BSX19	22171
VT6		Transistor BSX19	22171
VT7		Transistor BSX19	22171
VT8		Transistor BSX19	22171
VT9		Transistor BSX19	22171
VT10		Transistor BSX19	22171
VT11		Transistor BSX19	22171
VT12		Transistor BSX19	22171
VT13		Transistor BSX19	22171
VT14		Transistor BSX19	22171
VT15		Transistor BSX19	22171
VT16		Transistor MP53640	24128
VT17		Transistor 2N3905	20818
VT18		F.E. Transistor MPF102	
VT19		Transistor BSX19	22171
VT20		Transistor 2N3905	20818
VT21		Transistor BSX19	22171
VT22		Transistor BSX20	23307
IC1		Integrated Circuit MC890P	
IC2		Integrated Circuit 6995879	
IC3		Integrated Circuit 6995879	
IC4		Integrated Circuit 6995879	
IC5		Integrated Circuit 6995879	
IC6		Integrated Circuit 6995879	
IC7		Integrated Circuit 6996079	27347
IC8		Integrated Circuit 6996079	

Circuit Ref	Value	Description				Part No.
CAPACITORS (Cont)						
C10	22p		10%	500V		
C11	15p		10%	500V		22366
C12	15p		10%	500V		22366
C13	15p		10%	500V		22366
C14	22p		10%	500V		22368
C15	15p		10%	500V		22366
C16	15p		10%	500V		22366
C17	22p		10%	500V		22368
C18	.05μF		20%	12V		19657
C19	22p		10%	500V		22368
C20	22p		10%	500V		22368
C21	15p		10%	500V		22366
C22	15p		10%	500V		22366
C23	22p		10%	500V		22368
C24	15p		10%	500V		22366
C25	15p		10%	500V		22366
C26	15p		10%	500V		22366
C27	22p		10%	500V		22368
C28	15p		10%	500V		22366
C29	.05μF		20%	12V		19657
C30	10.000pF		25%	250V		22395
C31	0.1μF	+80%	+80%	30V	Lemlac	19647
			-20%			
C32	.22μF		10%	460V		2601
C33	4.7μF		10%	100V		
C34	.05		20%	12V		19657 C35
C35	.05		20%	12V		19657
MR1		Diode 1S44				18970
MR2		Diode 1S44				18970
MR3		Diode 1S44				18970
MR4		Diode 1S44				18970
MR5		Diode 1S44				18970
MR6		Diode 1S44				18970
MR7		Diode 1S44				18970
MR8		Diode 1S44				18970
MR9		Diode 1S44				18970
MR10		Diode 1S44				18970
MR11		Diode 1S44				18970

Circuit Ref	Value	Description	Part No.
MR12		Diode 1S44	18970
MR13		Diode 1S44	18970
MR14		Diode 1S44	18970
MR15		Diode 1S44	18970
MR16		Diode 1S44	18970
MR17		Diode 1S44	18970
MR18		Diode 1S44	18970
VT1		Transistor BSX20	23307
VT2		Transistor BSX19	22171
VT3		Transistor BSX19	22171
VT4		Transistor BSX19	22171
VT5		Transistor BSX19	22171
VT6		Transistor BSX19	22171
VT7		Transistor BSX19	22171
VT8		Transistor BSX19	22171
VT9		Transistor BSX19	22171
VT10		Transistor BSX19	22171
VT11		Transistor BSX19	22171
VT12		Transistor BSX19	22171
VT13		Transistor BSX19	22171
VT14		Transistor BSX19	22171
VT15		Transistor BSX19	22171
VT16		Transistor MPS3640	24128
VT17		Transistor 2N3905	20818
VT18		F.E. Transistor MPF102	
VT19		Transistor BSX19	22171
VT20		Transistor 2N3905	20818
VT21		Transistor BSX19	22171
VT22		Transistor BSX20	23307
IC1		Integrated Circuit MC890P	
IC2		Integrated Circuit 6995879	
IC3		Integrated Circuit 6995879	
IC4		Integrated Circuit 6995879	
IC5		Integrated Circuit 6995879	
IC6		Integrated Circuit 6995879	
IC7		Integrated Circuit 6996079	27347
IC8		Integrated Circuit 6996079	

Circuit Ref	Value	Description	Part No.
IC8		Integrated Circuit 6996079	27347
IC9		Integrated Circuit 6996079	27347
IC10		Integrated Circuit 6996079	27347
IC11		Integrated Circuit 6996079	27347
IC12		Integrated Circuit 6996979	27347
ILP1		Numicator ZM1172	
ILP2		Numicator ZM1172	
ILP3		Numicator ZM1172	
ILP4		Numicator ZM1172	
ILP5		Numicator ZM1172	
ILP6		Numicator ZM1172	

6.3 TC9 INTERCONNECTION

Circuit Ref	Value	Description			Part No.
RESISTORS					
R70	270K	Cr. Carbon	5%	1/8W	1679
R71	10K	Cr. Carbon	5%	1/8W	11503
R72	2.7K	Cr. Carbon	5%	1/8W	311
R73	2.7K	Cr. Carbon	5%	1/8W	311
R74	2.7K	Cr. Carbon	5%	1/8W	311
R75	2.7K	Cr. Carbon	5%	1/8W	311
CAPACITORS					
C71	4700pF	GP Ceramic			22393
C72	4700pF	GP Ceramic			22393
C73	2200pF	GP Ceramic			22389
C74	2200pF	GP Ceramic			22389
VT1		Transistor 2N3055			3813
T1		Transformer			MT598
ILP7		Indicator Neon Hi-Vac 3L			12781
ILP8		Indicator Neon Hi-Vac 3L			12781
ILP9		Indicator Neon Hi-Vac 3L			12781
ILP10		Indicator Neon Hi-Vac 3L			12781
SWITCHES					
S1		Time Units			25664
S2		Function			25665
S3		Stop PBS1M Rendar			4881
S4		Start SP60 PBS/CO/1 Rendar			4208
S5		Reset PBS1M Rendar			4881
RV2/S6		Control Pot 5MΩ REV Log. with switch ABM AY45			25877
SOCKETS					
SK1		Belling Lee L1413 4mm Black Reset			25878
SK2		Belling Lee L1413 4mm Black Ground			25878

Circuit Ref	Value	Description	Part No.
SOCKETS (Cont)			
SK3		Belling Lee L1413 4mm Black Input C	25878
SK4		Belling Lee L1413 4mm Black Input B	25878
SK5		Belling Lee L1413 4mm Black 1MHz Out	25878
SK6		Belling Lee L1413 4mm Black Time Units Out	25878
SK7		Belling Lee L1413 4mm Black Ground	25878
SK8		Socket Jack Rendar MJ600/A Ext. Std.	2726
SK9		Connector 50Ω BNC UG1094/A Input A	1222
FS1	2.5A		21189

6.4 TC9 AMPLIFIER

Circuit Ref	Value	Description			Part No.
RESISTORS					
R1	1MΩ		10%	½W 350V	1171
R2	100K		5%	1/8W	319
R3	5.6K		5%	1/8W	787
R4	120K		5%	1/8W	5332
R5	120K		5%	1/8W	5332
R6	22K		5%	1/8W	1544
R7	8.2K		5%	1/8W	314
R8	33K		5%	1/8W	317
R9	4.7K		5%	1/8W	386
R10	1K		5%	1/8W	384
R11	1K		5%	1/8W	384
R12	6.8K		5%	1/8W	313
R13	6.8K		5%	1/8W	313
R14	1K		5%	1/8W	384
R15	2.2K		5%	1/8W	425
R16	33Ω		5%	1/8W	2931
R17	330Ω		5%	1/8W	1894
R18	27Ω		5%	1/8W	724
R19	390Ω		5%	1/8W	2410
R20	1.5K		5%	1/8W	385
R21	820Ω		5%	1/8W	1637
R22	330Ω		5%	1/8W	1894
R23	33Ω		5%	1/8W	2931
R24	15Ω		5%	1/8W	2085
R25	1.5K		5%	1/8W	385
R26	820Ω		5%	1/8W	1637
R27	220Ω		5%	1/8W	304
R28	1K		5%	1/8W	384
R29	33Ω		5%	1/8W	2931
R30	15Ω		5%	1/8W	2085
R31	330Ω		5%	1/8W	1894
R32	12K		5%	1/8W	1685
R33	1K		5%	1/8W	384
R34	12K		5%	1/8W	1685
R35	12K		5%	1/8W	1685
R36	1K		5%	1/8W	384

Circuit Ref	Value	Description			Part No.
RESISTORS (Cont)					
R37	2.7K		5%	1/8W	311
R38	12K		5%	125W	1685
R39	1.8K				310
R40	470				1373
R41	2.7K				311
R42	1.2K				2087
R43	1.2K				2087
CAPACITORS					
C1	0.1μF	Polyester	10%	400V	2385
C2	4.7pF	Silver Mica	±½pF	350V	4502
C3	4.7pF	Silver Mica	±½pF	350V	4502
C4	33pF	Silver Mica	5%	350V	4779
C5	68p	Silver Mica	5%	350V	4513
C6	100p	Ceramic	10%	500V	22376
C7	.047μF	Ceramic	+80% -20%	30V	2793
C8	.05μF	Ceramic	±20%	12V	19657
C9	.05μF	Ceramic	±20%	12V	19657
C10	200μF	Electrolytic	-10% +50%	10V	20782
C11	.047μF	Ceramic	+80% -20%	30V	2793
C12	.05μF	Ceramic	±20%	12V	19657
C13	.05μF	Ceramic	±20%	12V	19657
C14	200μF	Electrolytic	-10% +50%	10V	20782
C15	.05μF	Ceramic	±20%	12V	19657
C16	1000μF	Electrolytic	-10% +50%	6.4V	24797
C17	12pF	Ceramic	10%	500V	22365
C18	200μF	Electrolytic	-10% +50%	10V	20782
C19	.05μF	Ceramic	±20%	12V	19657
C20	220pF	Ceramic	±10%	500V	22379
C21	220pF	Ceramic	±10%	500V	22379
C22	68p	Ceramic	10%	500V	22374
C23	500μF	Electrolytic	-20% +50%	6V	1742

Circuit Ref	Value	Description			Part No.
CAPACITORS (Cont)					
C24	.05μF	Ceramic	20%	12V	19657
C25	200μF	Electrolytic	-10% +50%	10V	20782
C26	.05μF	Ceramic	20%	12V	19657
C27	18pF	Ceramic	10%	500V	22367
C28	15pF	Ceramic	10%	500V	22366
C29	.05μF	Ceramic	20%	12V	19657
C30	1000μF	Electrolytic	-10% +50%	6.4V	24797
MR1		Diode 1N916			1949
MR2		Diode 1S44			18970
VT1		F.E. Transistor MPF102			
VT2		Transistor BSX19			22171
VT3		Transistor 2N3662			24123
VT4		Transistor 2N3662			24123
VT5		Transistor 2N3662			24123
VT6		Transistor 2N3662			24123
VT7		Transistor BSX20			23307
VT8		Transistor BSX20			23307
VT9		Transistor BSX19			22171
S1		Switch 2 pole 3 way slider			
MR3		Diode ZF-15 Zener		15V	4669

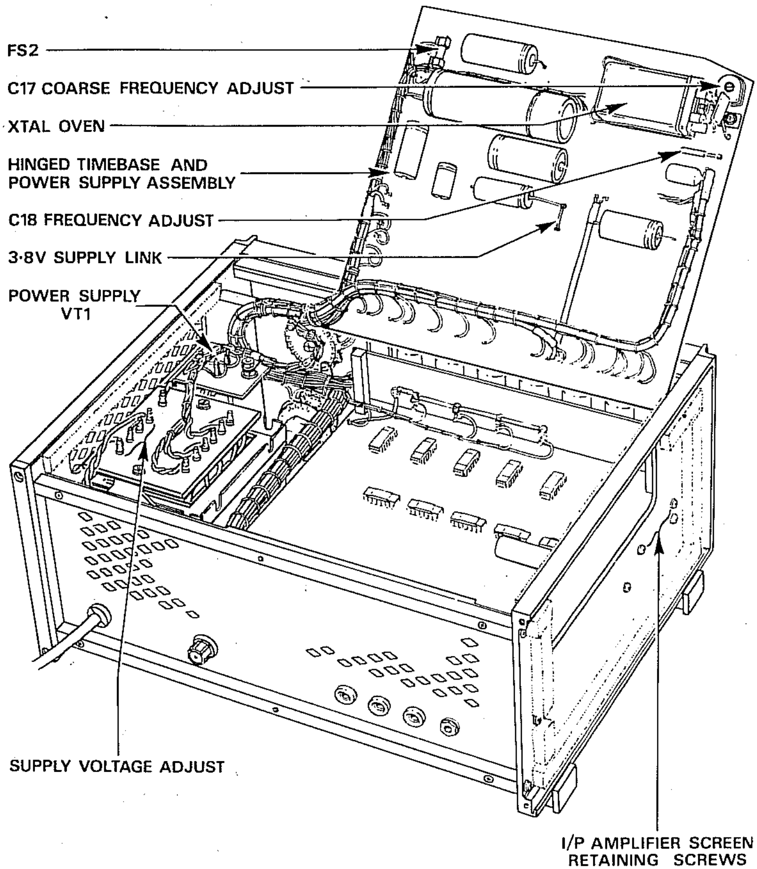


Fig. 6 Component Layout

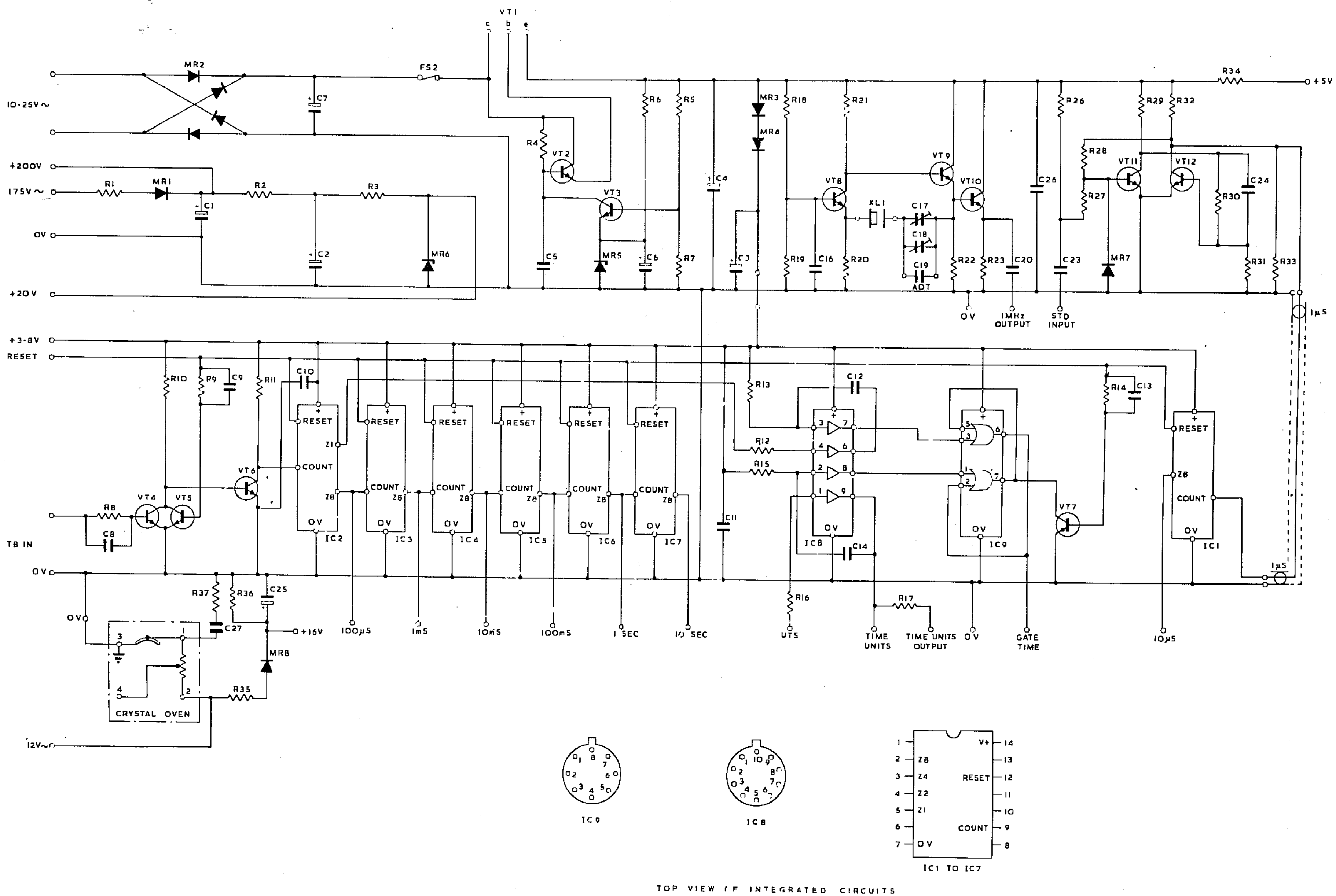


Fig. 2 Timebase and Power Supplies Circuit Diagram

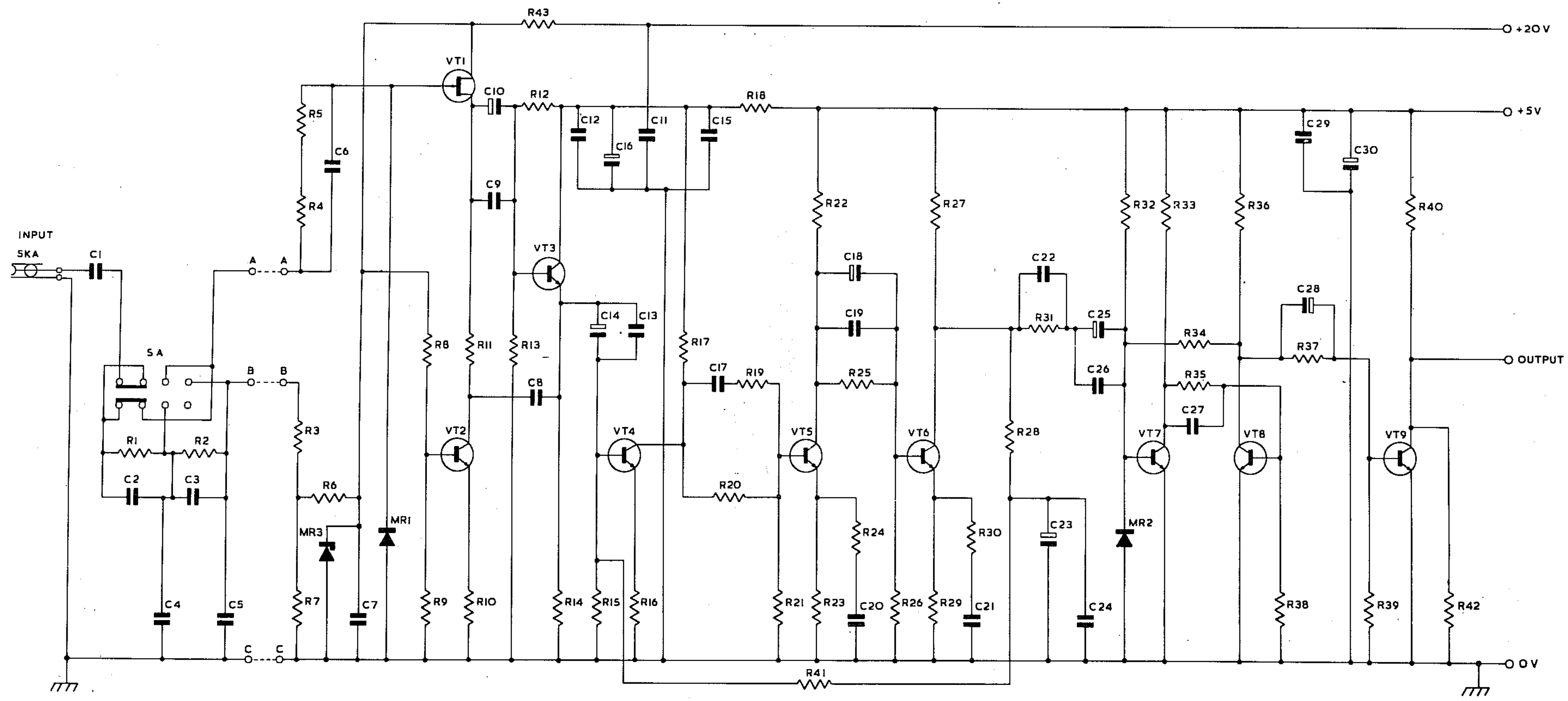


Fig. 3 Input Amplifier Circuit Diagram

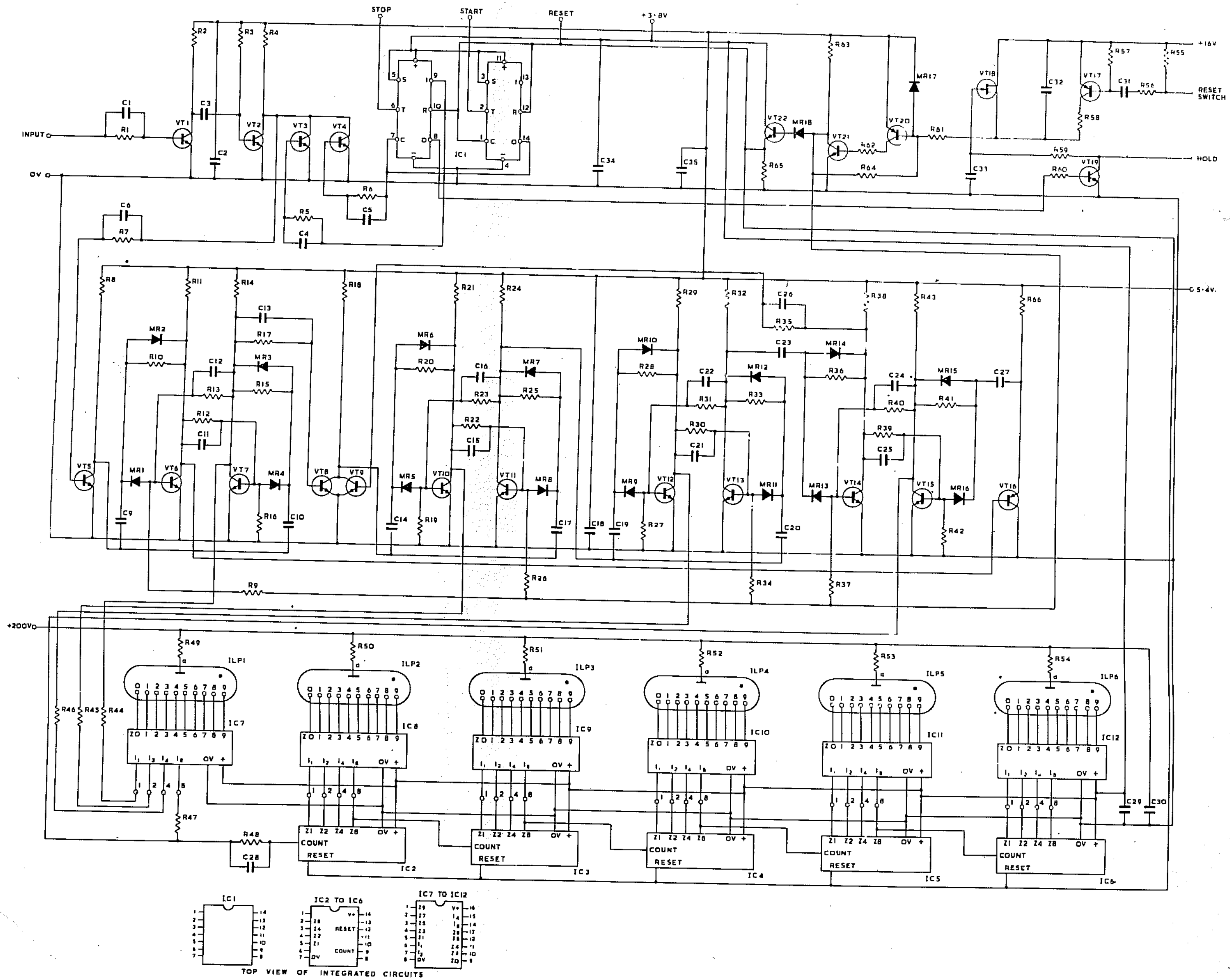


Fig. 4 Decade and Display Circuit Diagram

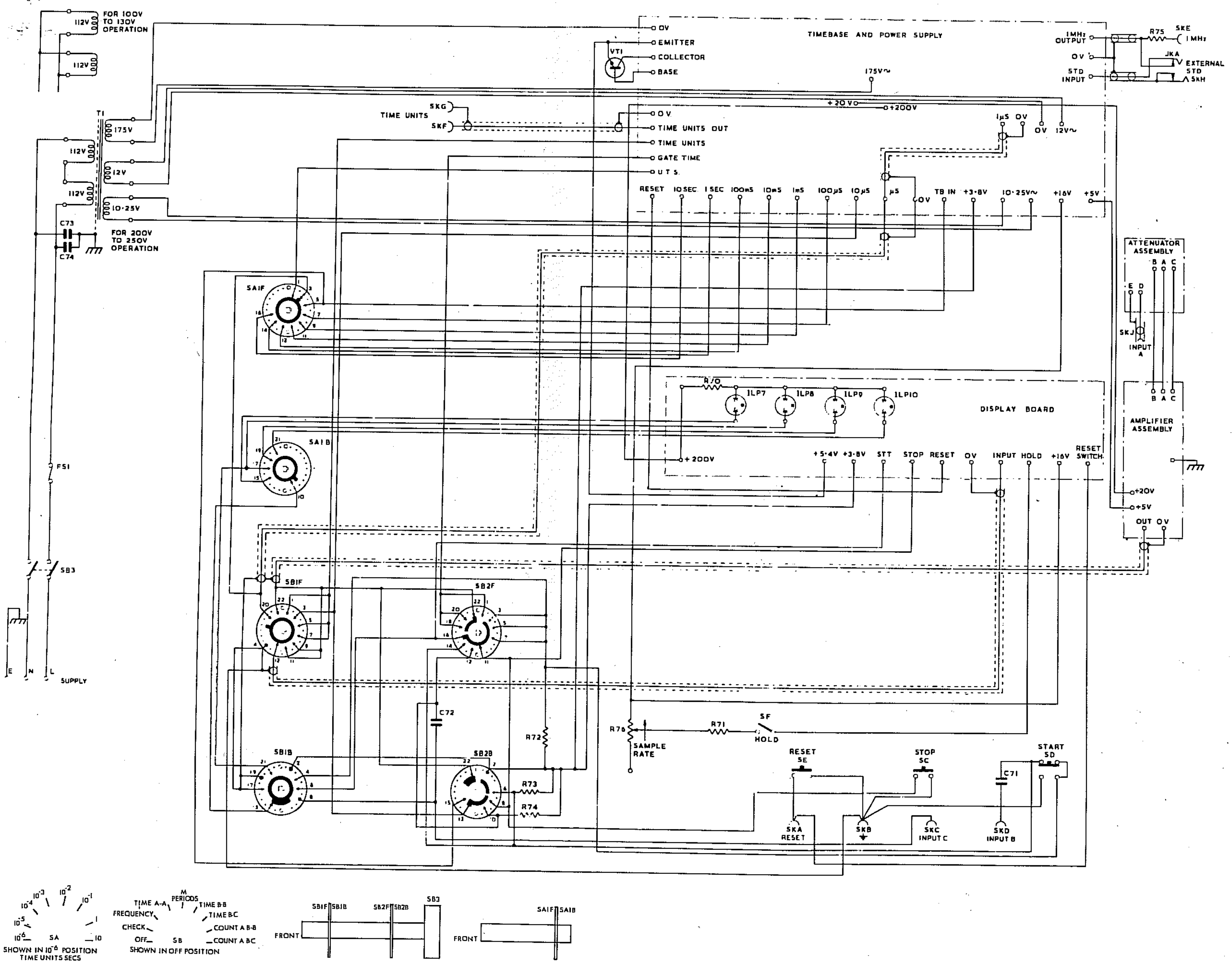


Fig. 5 Interconnection Diagram

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