SABTRONICS INSTRUMENTS

8ØØØ SERIES FREQUENCY COUNTERS

SERVICE MANUAL

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SABTRONICS INSTRUMENTS

8000 SERIES FREQUENCY COUNTERS

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SABTRONICS 8000 SERIES FREQUENCY COUNTERS

SERVICE MANUAL

INTRODUCTION

This manual is intended to provide information for servicing the 8000 series Frequency Counters, manufactured by Sabtronics Instruments.

The models included in this series are:

Model 8000B & C - covers frequencies up to 1GHz

Model 8610B - covers frequencies up to 600MHz

Model 8500C - covers frequencies up to 1.5GHz

These models use a common circuit for the main counting function, and a selection of prescalers to provide the differing frequency coverage. Consequently, the approach used in this manual will be to describe the main counter circuit, detailing any differences between models, and to separately describe the various prescalers that have been used.

Maintenance Requirements

A certain amount of basic test equipment, and a few tools are needed to perform effective maintenance and adjustment on the 8000 series counters.

The following items are essential:

i) Sabtronics Mains Adaptor, or suitable bench power supply, 12 volts at 500mA.

ii) Multimeter, either analogue or digital.

iii) Signal Generators, to cover the ranges of the counter to be tested. If the output level of the generators is not variable then a suitable RF variable attenuator is required as well.

iv) An Oscilloscope, preferably with a bandwidth of at least 20MHz, and with a dual beam facility. 10Mohm, x10 probes should be used and the scope should have a sensitivity of at least 5mV per division.

v) BNC through termination.

Tools required are:

Screwdrivers, posidrive No 2 and small instrument types.

Soldering iron (temperature controlled) and fine solder (22 gauge is recommended)

Desoldering tool - preferably the `bicycle pump' type, or full PCB workstation. Desolder wick is not recommended for working on boards with fine tracks.

Hand tools - small pliers and cutters, and an insulated trimming tool.

Test Leads - a selection of coax and single wire test leads; a coax lead with a BNC plug on one end and two crocodile clips on the other can be particularly useful.

SECTION 1

COMMON FEATURES OF THE 8000 SERIES

Mechanical Construction

All of the models in the 8000 series share a common mechanical construction. The case is moulded in two parts, with slots to hold the front and rear panels. Inside, the Main Counter Board is supported by four screws into bushes on the rear side of the front panel.

To open the case, first remove the handle by springing it open. Turn the Counter upside down and remove the three screws from the base. With unit still inverted, remove the bottom case half, leaving the front and rear panels in the inverted top half of the case.

The method of mounting the Main Counter Board to the front panel, and of attaching the Prescaler to the Main Board can now be seen.

The two battery clips can be sprung out of their positions in the battery compartment, and the front and rear panels, complete with the circuit boards and power connector, can now be removed from the upper case half.

To separate the Main Counter Board from the front panel, undo the screw to be found at each corner of the board. This will leave the Main Board attached to the front panel by the two input cables. If major fault investigation or other work is to be done on the Main Board, it will be found easiest to detach these two cables from the board and the Prescaler, and replace them temporarily with short lengths of suitable cable terminated in BNC sockets.

The counter can be put back together by reversing the above procedure. Take care, however, that the cables do not foul the internal pillars of the case, particularly in the area of the Prescaler.

SECTION 2

MAIN COUNTER BOARD

CIRCUIT DESCRIPTION

Overall Outline

All the 8000 series counters use the same Main Counter board, with some minor variations.

The circuit of the main counter board is given in Fig 2.1. The functions contained on this board are as follows:

Power supply regulation and NiCad charging

Input amplifier and signal conditioning up to 100MHz

Digital divider

Reference oscillator and counting circuit

9 digit display, with leading zero suppression and automatic decimal point positioning

Switching for all functions

Power Supply Circuits

The power supply circuits regulate the incoming voltage from the Mains Adaptor, provide a suitable voltage for charging NiCad batteries, and enables the unit to be powered by the NiCad batteries in the absence of a Mains supply.

The functions of the power circuit are controlled by the switch, SW1. When it is in the OFF position power is not supplied to the counter circuits. The regulator circuit is still powered though, provided that the Mains Adaptor is connected. Under this condition the regulator IC4, has its output voltage increased due to the three series diodes in its ground connection. This voltage is fed through the output series diode, CR3, and the 6R8 resistor to charge the NiCad battery. Note that there is no method of turning the charging facility off, so cells other than NiCads should not be used to power these Frequency Counters. The use of other types of battery could be a safety hazard.

When SW1 is moved to the ON position two of the diodes in the ground path of IC4 are shorted out. This lowers the output voltage of IC4 by approx. 1.2V. The counter circuits are supplied with power, either from the NiCad batteries, if installed, or from the mains Adaptor, via the regulator, IC4.

The series output diode is necessary to prevent the NiCad battery backfeeding the regulator output, as the 6R8 resistor is shorted out when SW1 is in the ON position. CR4, the diode that is permanently in the ground path of IC4, is provided to compensate for the voltage drop caused by the series output diode, CR3.

The net result of this is that 5V should be supplied to the counter circuits, whether it be from NiCads or from the Mains Adaptor. The standard Mains Adaptor will give a voltage of between 9 and 12 volts DC - it is not advisable to run the counters from a voltage higher than this as the heatsink on IC4 is not intended to cope with any higher input voltages.

Input Amplifier and Signal Conditioning

The Input Amplifier, served by the A channel input is operational when the counter is switched to the 10MHz and 100MHz ranges. It is a high impedance input, presenting a load of nominally 1Mohm in parallel with 30pF to the circuit under test. C1 provides DC isolation and CR1 and 2 prevent the signal voltage fed to the counter from being too high. R1 determines the effective input impedance, whilst Q1 and Q2 form an impedance converter, to match the input into Z1. These two transistors are also arranged to provide the correct DC bias for Z1, adjusted by R3 and measured at TP1.

Z1 has three stages of amplification, of which the second two stages have some feedback round them. The output of Z1 is fed into Q3 and Q4, connected as a long tailed pair, to convert from the ECL levels of Z1 to the TTL levels of Z2. The output to Z2 is taken from R17, in the collector of Q4. The routing of the output depends on the counter model.

Digital Divider

Z2 is a TTL IC containing divide by 2 and divide by 5 functions. On the 10MHz range of all models it is programmed to act as a buffer, giving no division at all. SW2b sets pin 1 of Z2 to ground on the 10MHz position, and in this state the Qc output follows the C input. In the other two psitions of SW2, pin 1 is at +5v, and the circuit will divide. On models 8610B and 8500C, the two functions are connected in series to provide a total division of 10. On the 8000B and C models only the divide by five is used. The difference on the circuit board is determined by the connections used for the two coaxial cables from SW2 to Z2.

On all models the output from Q4 is taken to SW2 by a coax cable from point D on the board to point B (point DD is the ground connection associated with D, as BB is for Point B). The signal output from the switch is returned to Z2 from point A and AA (ground). On the 8610B, C and 8500C models this cable is connected to points C and CC, thus using the full divide by 10 function of Z2. Points E and F are linked together. On the 8000B and C this cable is connected to points E and EE, and points C and D are linked. On all models, and on both ranges using the A input the Qc output of Z2 is used, as this gives an almost 1:1 duty cycle to the output waveform.

Reference Oscillator and Main Counter

Z3 is a complex VLSI IC which is the heart of the counter. It contains the reference oscillator circuit and dividers, all the timing and gating circuits, the counters themselves and all the display driving circuitry. It is not appropriate to go into great detail here about this IC, but a brief synopsis of its functions and signals will be given.

Reference Oscillator
A crystal connected between pins 25 and 26 can be used to provide a stable reference source for the counting circuits. R19 and C13 provide the necessary feedback for the oscillator circuit, and C11 and 12 enable the frequency of the oscillator to be precisely adjusted. The oscillator signal is internally divided to give the various signals needed for the counter to function.

Counter Input

The signal to be counted is connected to pin 28. It must have a 1:1 duty cycle, and be of sufficient amplitude (low=<1 volt and high=>3.5 volts). R22 is a pull up resistor, to give a good level of immunity against noise.

Range Input

Pin 14 is used to decide how long the Gate should be open for; in other words how long the counter counts the input for each time that it updates the display. This corresponds to the 0.1, 1 and 10 second positions of SW3.

Decimal Point Input

When external dividers, such as Z2 and the prescalers are used to extend the frequency coverage of the counter, it needs to be told where to position the decimal point for the correct frequency to be displayed.

Digit Drives

There are 8 digit drive outputs, one for each main display digit. In conjunction with the Segment Drives they give the necessary `multiplexed' information for the display to function. All the multiplexing signals are generated within Z3.

The digit drives also control the functions, range and decimal point position of Z3 and the display. The internal circuitry expects to see digit drive signals returned via the Range Input, Decimal point Input and Control Input pins, and depending on the actual digit drive returned, it will take appropriate action.

On all models the Gate Times are as follows:

Ø.1 sec	D2 returned
1 sec	D3 returned
1Ø sec	D4 returned

The Decimal Point positioning is more complex, and depends on the positions of both SW2 and SW3. For the 8ØØØ and 861Ø models it is as follows:

	Gate Time (SW3)		
Range	Ø.1s	1s	1Øs
1ØMHz	D6	D7	D2
1ØØMHz	D5	D6	D7
6ØØ/1ØØØMHz	D4	D5	D6

On model 85ØØC the lower two ranges are as above, but the 1.5 GHz range is:

15ØØMHz	D3	D4	D5

This difference is made by cutting the PCB tracks on the back of SW3 and restrapping the connections.

Segment Drives

These provide the information used with the digit drives to control the display. There is one wire for each of the seven segments of the standard display, and one for the decimal point.

Control Input

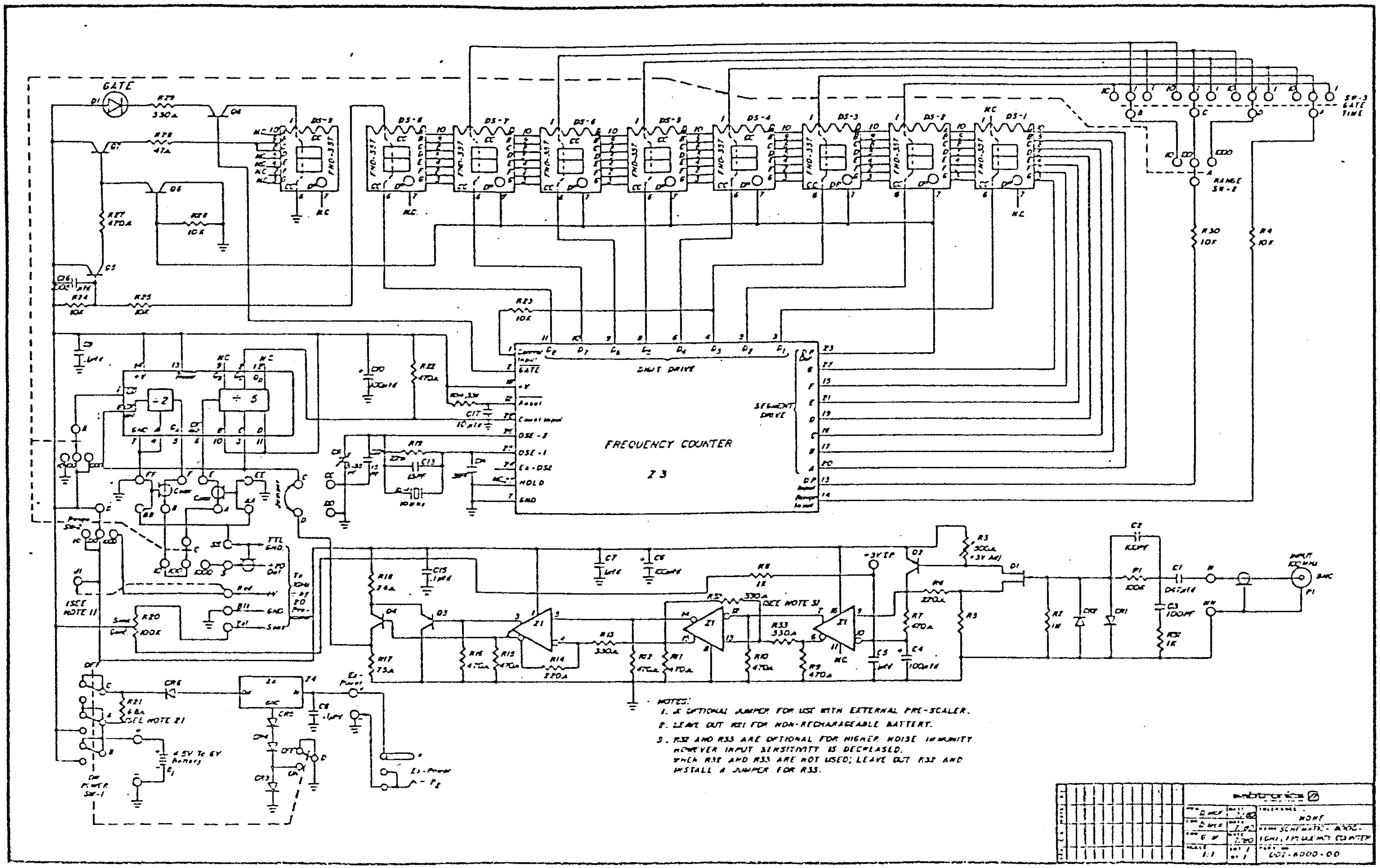
By feeding back the digit drives to pin 1, the Control Input the different modes of operation of Z3 are enabled. The only one that is of significance in this application is Digit 3, which tells the IC to use the information presented at pin 13, the Decimal Point Input, rather than to use its own internal information. For a full description of the modes of operation see the Intersil Data Sheet for the ICM7216A/B/C/D.

Gate (Measurement In Progress)

The IC provides an output which indicates when the Gate is open, ie when it is actually counting. This is used to drive the LED, D1 via Q8 and R29.

Z3 is an 8 digit counter IC. One of its properties not mentioned above is that it uses the decimal point of digit 8 to indicate an `overflow' condition; ie the count is greater than Z3 can display. All models of the 8000 series detect this condition and display the overflow as the ninth digit.

This detector is made up of Q5 -7, R24 - 28 and C16. It simply gates together the decimal point output and the digit 8 drive from Z3. If they are in the overflow state then the b and c segments of digit 9 are illuminated to show a `1'.


GATE
DS-9
DS-8
DS-7
DS-6
DS-5
DS-4
DS-3
DS-2
DS-1
FND-357
SW-3 GATE TIME
RANGE SW-2
FREQUENCY COUNTER
Z3
DIGIT DRIVE
SEGMENT DRIVE
INPUT 100 MHz
BNC
POWER SW-1
4.5V TO 6V Battery
Ex-Power
NOTES:
1. Æ OPTIONAL JUMPER FOR USE WITH EXTERNAL PRE-SCALER.
2. LEAVE OUT R21 FOR NON-RECHARGEABLE BATTERY.
3. R32 AND R33 ARE OPTIONAL FOR HIGHER NOISE IMMUNITY
HOWEVER INPUT SENSITIVITY IS DECREASED.
WHEN R32 AND R33 ARE NOT USED; LEAVE OUT R32 AND
INSTALL A JUMPER FOR R33.
NONE
SCHEMATIC - 100C-
1GHz, FREQUENCY COUNTER
1:1
607-A000-00

SECTION 3

PRESCALERS

Model Variants

Several different prescalers have been used in the series of Frequency Counters covered by this Manual. There are common factors amongst them, however, dictated by the fact that they operate into a common main circuit board. The maximum frequency that the main board can handle is 100MHz, so any prescaler must divide its input to give an output frequency of 100MHz or less. Also, since the reference oscillator on the main board is fixed at 10MHz, the division ratio of the prescaler must be a multiple of 10 for the frequency display to be correct. (The 100MHz range of the counter incorporates division as well, giving an overall division of 100 or 1000).

In all the prescalers used, there is also some amplification to increase the measuring sensitivity. Integrated circuits have been used to provide this amplification.

Each prescaler will now be described, with the models on which they are to be found identified.

PSC-1000

This is a 1GHz divide by 20 prescaler. A further divide by five is provided by Z2 on the main board, giving an overall total of divide by 100. Thus 1000MHz at the prescaler input is fed to the main board as 50MHz, and divided down to 10MHz to be counted.

The circuit diagram of the PSC-1000 is given in Fig 3.1. Z1 is the amplifier stage, with the input connected to pin 3 via C1 which provides DC blocking. The inverting input, pin 4, is used to vary the gain of the amplifier, and thus control the sensitivity of the prescaler. Differential outputs from the IC are terminated, one to ground via C3 and R3, and the other into the input of the first divider stage, Z2, via C4 and R4.

Z2 is a divide by two circuit, with a maximum frequency capability of over 1000MHz. The input is pin 4, and as it is an ECL IC, it derives its own bias level from the input. This bias must be decoupled; C6, on pin 6 does this. This IC also has differential outputs, one terminated to ground as with Z1, and one fed to the second divider stage, Z3, via C11 and R5.

Z3 is a divide by ten stage, which will work to over 650MHz. It also gives TTL level outputs, and is thus ideally suited to this type of application. It should be noted that the TTL output has a separate ground connection.

The power supplies to the IC's on the precaler board are decoupled by C1Ø, C8 and the RFC. Each IC also has its own individual decoupling, C5 (Z1), C9 (Z2) and C7 (Z3).

This prescaler is fitted to early model 8ØØØB Frequency Counters.

PSC-1ØØØ-1

This is a later version of the above prescaler, due to the fact that the IC used for Z1 in PSC-1ØØØ was discontinued. The circuit diagram of PSC-1ØØØ-1 is shown in Fig 3.2. It is so similar to the circuit already described that no further explanation is warranted, except a cautionary note that the IC's used for Z1 in the two versions are not pin compatible.

This prescaler is found in later versions of the model 8ØØØB Frequency Counter.

PSC-6ØØ

This is a 6ØØMHz divide by 1Ø prescaler, and is found in the model 861ØB. It is a modification of the PSC-1ØØØ-1 prescaler used in the model 8ØØØ.

The modification is to leave out Z2 of the PSC-1ØØØ-1, and its associated components. This is shown in the circuit diagram, Fig 3.3. Z2, R4,5 and C11 are not used, and the output of Z1 is linked directly to the input of Z3, via C6.

This prescaler uses the same PCB as the PSC-1ØØØ-1, and the components that are used are the same values as the corresponding components in the PSC-1ØØØ-1.

PSC-1ØØØ-2

This prescaler is also a divide by 2Ø unit working to over 1ØØØMHz. The divider circuitry is the same as PSC-1ØØØ-1, but an improved amplifier arrangement is used to give a better sensitivity at 1GHz.

The circuit diagram is given in Fig 3.4. The input is via R1 and R2, which form an attenuator, to prevent the amplifier, Z1, from being overloaded. C1 provides DC blocking into IC1, which is a high performance CATV type amplifier giving about 25dB of gain at 1GHz. Unlike the prescalers so far examined, the amplifier used in this one does not have differential inputs, and therefore does not allow the sensitivity control to be implemented.

The output of IC1 is taken via C4 to IC2. L1 also connects to the output of IC1; this is to provide the supply voltage for the open-collector output stage of the amplifier, L1 thus forming the collector load. From the input of IC2 onwards the signal path is the same as for PSC-1000-1.

The only other major difference is that the 5V line from the main counter also powers a relay. This is to switch the +12V required for IC1. This places a limitation on the power supply for counters using this type of prescaler; the mains adaptor should have a 12V output rather than the normal 9V. As a practical note the performance of the prescaler is still reasonable when run from a 9V supply.

This prescaler is to be found in model 8000C Frequency Counters. These counters have no Sensitivity control on the front panel, unlike the 8000B's.

PSC-1500-1

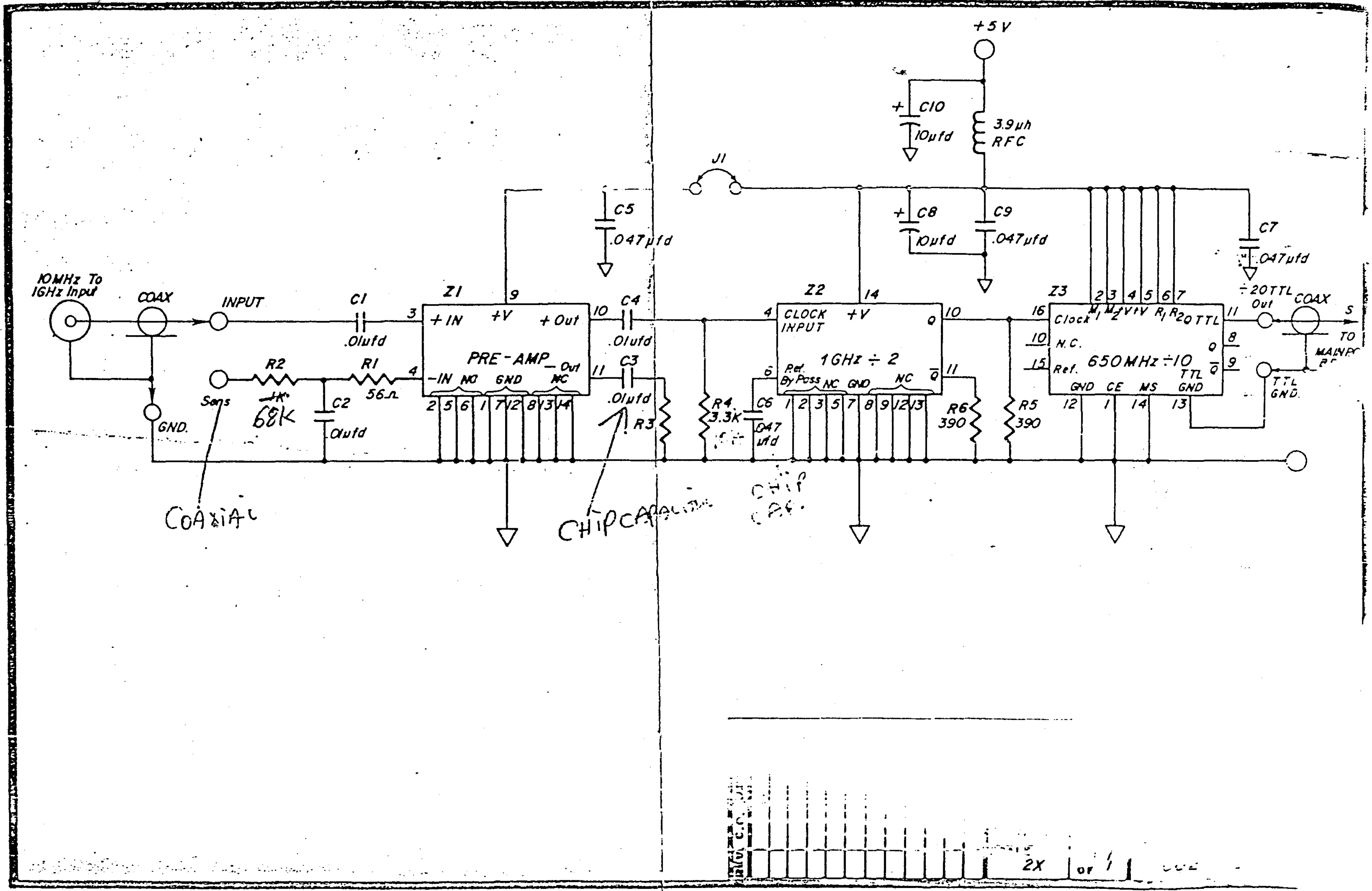
This prescaler is a divide by 100 unit, capable of working to frequencies in excess of 1.5GHz. The circuit diagram is given in Fig 3.5.

It uses the same amplifier as the PSC-1000-2, but this is followed by two divide by 10 stages. C1 provides DC blocking into IC1, and C4 isolates the output. The attenuator, R1 and R2, is placed between IC1 and IC2, to give the best performance at the highest frequencies.

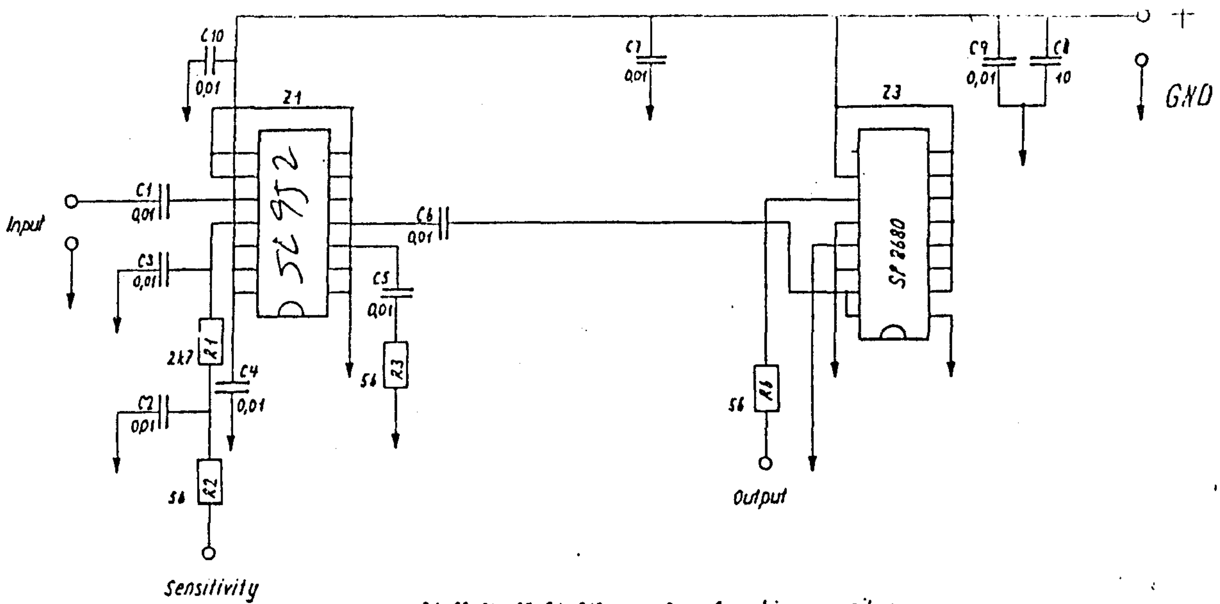
IC2 is a divide by ten stage, working to over 1500MHz. In order to achieve this performance, IC2 needs a supply voltage of +6.2v. This is provided by IC4, a low power regulator, with R3 and VR1 determining a `pedestal' voltage for the ground terminal of the IC. This effectively raises the output voltage of the fixed regulator by the pedestal voltage.

The output of IC2 is coupled to the input of IC3 by R4, R5 and C9, which form a matching network so that both the output and input see the correct conditions. IC3 is a divide by ten stage up to about 180MHz. Like other ECL IC's it's input bias needs decoupling, via C8. R6 is to prevent the IC self-oscillating in the abscence of input signal. R2 serves the same function for IC2. The output from IC3 is TTL compatible, and is connected to the main counter board.

IC3 needs a 5v supply, which is provided by IC5, directly off the 12v rail. As with the PSC-1000-2, te 12v supply is switched by a relay, RLA, operated from the +5v switched by the main board. This prescaler is used in the model 8500C Frequency Counters.



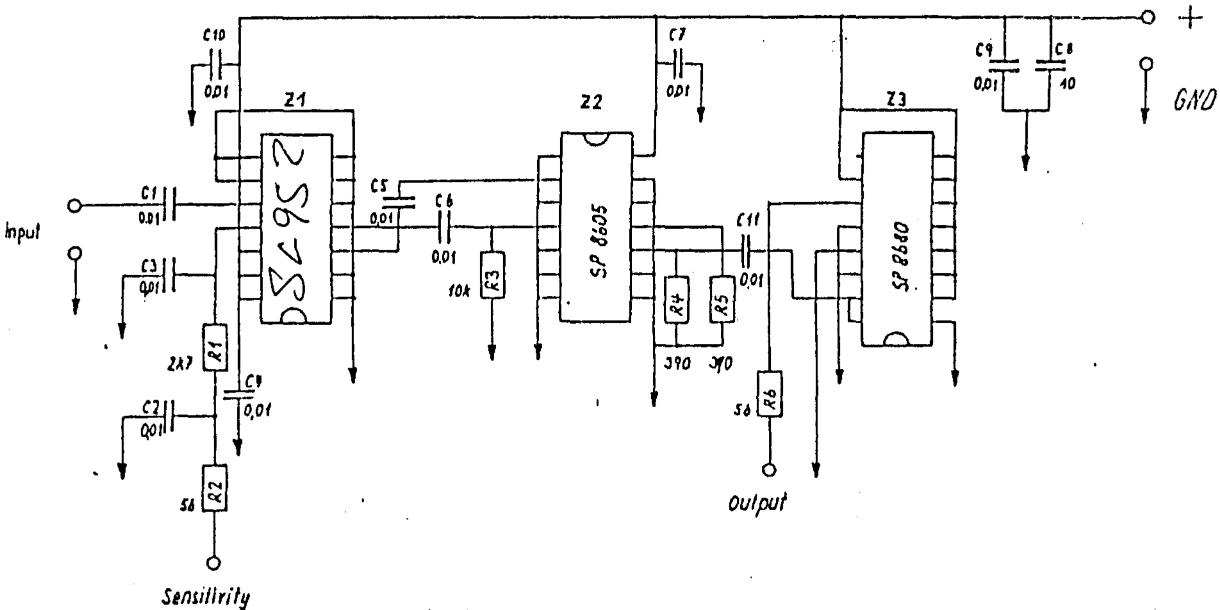
10MHz To 1GHz Input
COAX
INPUT
GND.
Sens
C1 .01ufd
R2
R1 56Ω
C2 .01ufd
Z1
PRE-AMP
+IN
+V
+Out
-IN
NC
GND
- Out
C5 .047ufd
C4 .01ufd
C3 .01ufd
R3
R4 3.3K
C6 .047 ufd
J1
Z2
CLOCK INPUT
1GHz ÷ 2
Ref. By Pass
R6 390
R5 390
+5V
C10 10ufd
3.9uh RFC
C8 10ufd
C9 .047ufd
C7 .047ufd
Z3
650MHz ÷10
Clock
N.C.
Ref.
CE
MS
TTL GND
÷20TTL Out
TTL GND.
COAX
TO
COAXIAL
CHIP CAP.
2X



C1, C3, C4, C5, C6, C10: 0,01 µF chip capacitor

REV	C.O.	DATE	BY			
				sabtronics INTERNATIONAL INC		
				DRN Ovinter	DATE 6.7.83	TOLERANCE ± .005 PSC 1000-3
				CHK G S	DATE 8.7.83	NAME 600MHZ ./. 10 PRESCALER
				ENG P C	DATE 1.7.83	
				SCALE	SHT OF	PART NO. B1810

Fig 3.3 PSC 600



C1, C3, C4, C5, C6, C10: 0,01 µF chip capacitor

REV	C.O.	DATE	BY			
				sabtronics INTERNATIONAL INC		
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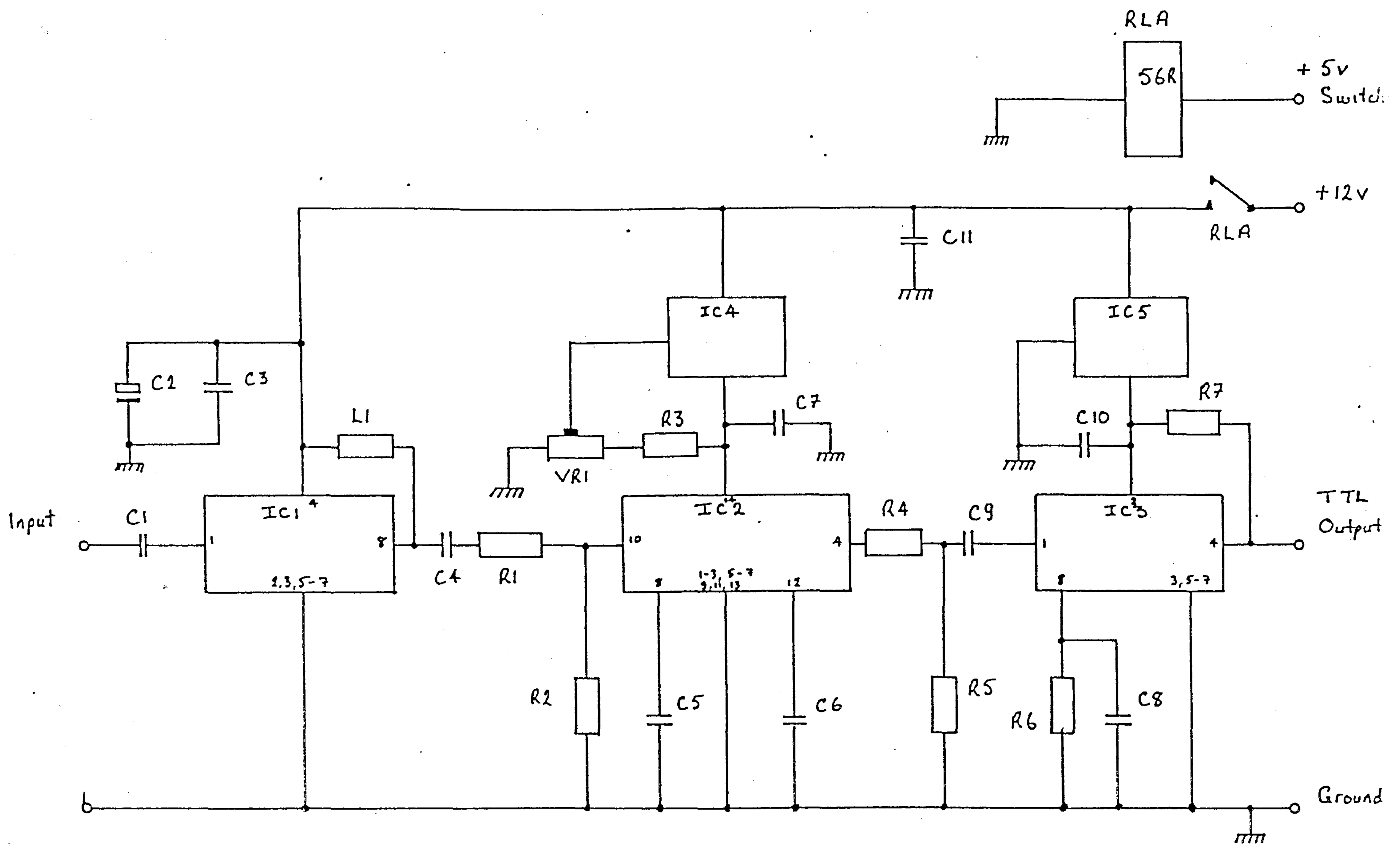
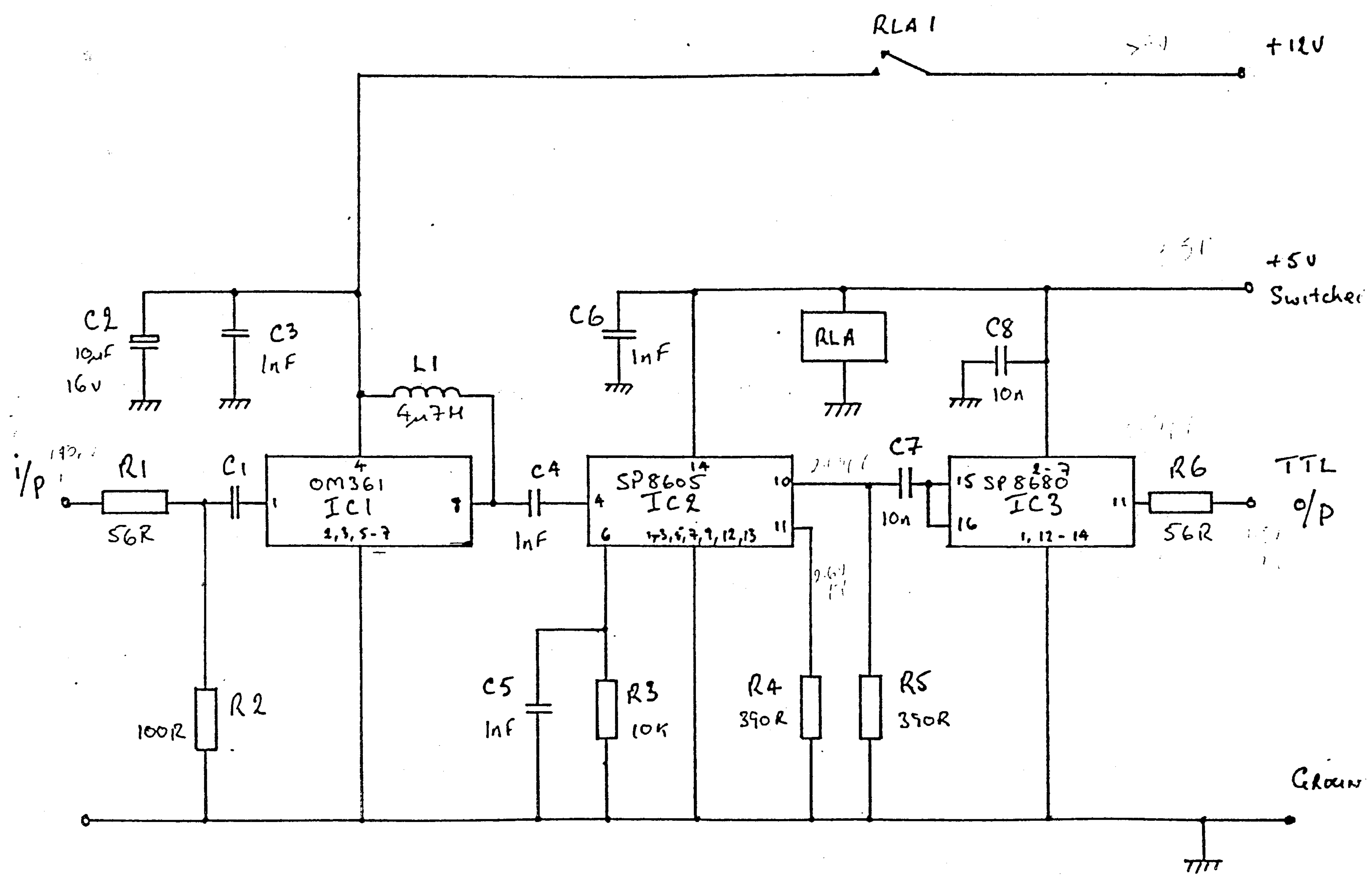
				CHK G S	DATE 8.7.83	NAME 1GHZ ./. 10 PRESCALER
				ENG P C	DATE 1.7.83	
				SCALE :	SHT OF 1/1	PART NO. B1810

Fig 3.2



Sabtronics PSC 1500-1 Circuit Diagram



Sabtronics PSC 1000-2-07

Circuit Diagram

17/11/83 DSP

SECTION 4

CALIBRATION AND ADJUSTMENT

Main Counter Board

There are only two adjustments on the main board:

R3, which sets the operating point for Z1, and

C11, which adjusts the frequency of the reference oscillator.

R3 is adjusted to give 3v (+0.2v) at TP1. Component locations are shown in Fig 4.1. This test point may be accessible through the small hole in the front panel, but a long thin test probe is needed. It much easier if the front panel and the main board are seperated, although there is just enough room for access if the cables to the BNC sockets are left in place.

No input signal is needed for this adjustment; it is a DC measurement, and requires only that the power is connected and the counter switched on.

The reference frequency adjustment, C11, is also accessible through the front panel. The adjustment is easiest performed by using an input signal of known high accuracy, such as a synthesized signal generator. A better alternative to a signal generator is an `off-air' frequency standard, such as the Burns SD 12. If such a source is not available then an alternative method of adjustment using a radio receiver will be given.

The counter should be switched on and allowed to reach a stable operating temperature; at least 15 minutes, and preferably longer to ensure that the crystal and other components have stabilised.

To perform the adjustment using a signal generator, set the gate time to 1 second, and connect the signal to the appropriate input: it does not matter what the frequency is provided that it is accurately defined, and that the correct range of the counter is used. Using an insulated trimming tool, adjust C11 for a correct display.

When a correct display is obtained, switch the gate time to 10 seconds, and adjust out any minor errors remaining. This part of the adjustment process can be time consuming!

To adjust the reference using a radio receiver can be quicker. The radio must be able to receive the appropriate local 10MHz Standard Frequency Transmission. If the counter is stood close by the radio, an audible beat note may be heard between the counter's reference oscillator, picked up by the radio, and the Standard Frequency Transmission. Adjust C11 for zero beat.

Prescalers

Generally there are no adjustments on the prescalers used in the 8000 series counters. The only exception is the PSC-1500-1, used in the model 8500C. This prescaler needs the supply voltage for IC2 to be set to 6.1 (+0.1)v. Adjust VR1, and measure between pin 14 of IC2 and ground.

Note that this measurement is set up in manufacture, and would normally only be readjusted if IC4 has been replaced.

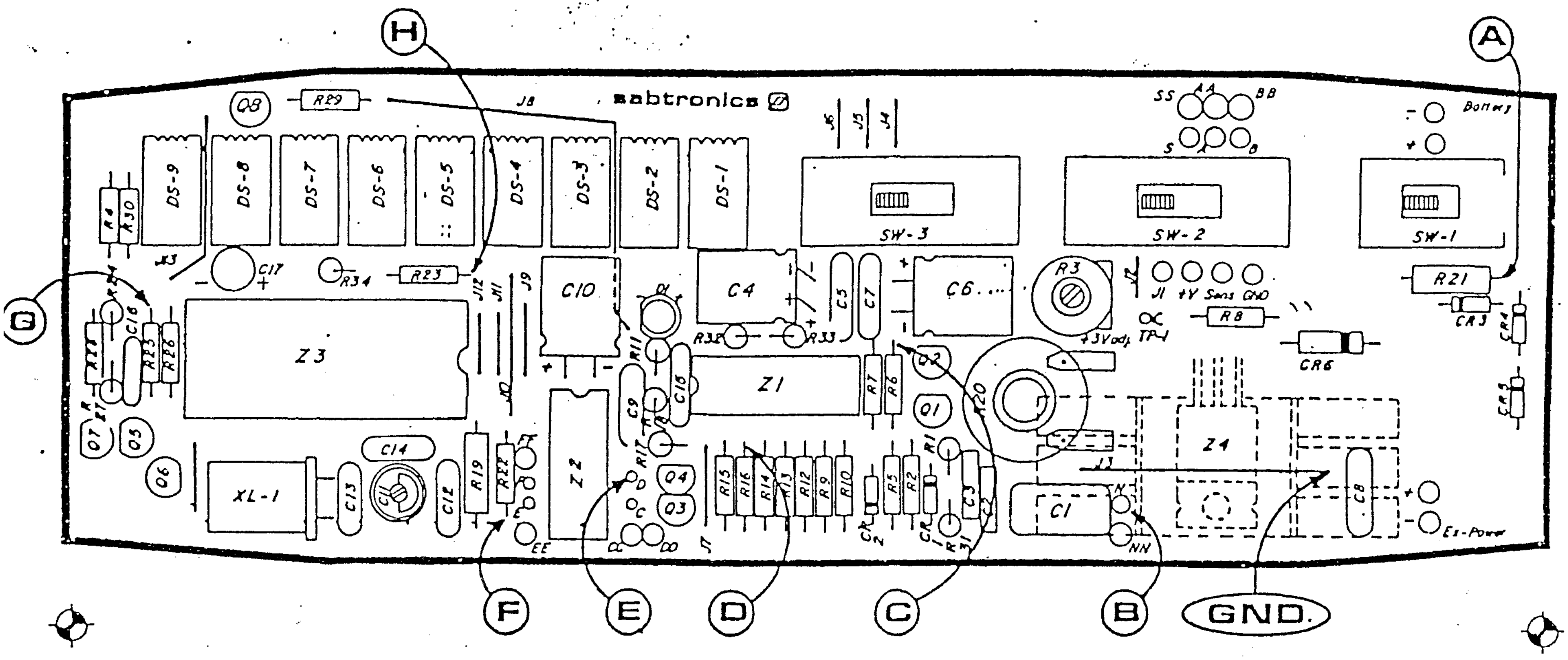

sabtronics
DS-1
DS-2
DS-3
DS-4
DS-5
DS-6
DS-7
DS-8
DS-9
SW-1
SW-2
SW-3
Z1
Z2
Z3
Z4
XL-1
C1
C4
C6
C8
C10
GND.
A
B
C
D
E
F
G
H
Battery
Ex-Power
J1 +V Sens GND
TP-1
+3Vadj

FIGURE 6

SECTION 5

FAULT FINDING

General

As with any equipment, many faults can be isolated to a particular part of the circuit by careful consideration of the symptoms. To aid in the location of faulty components Fig 5.1 shows the circuit diagram of the main counter board with the voltage levels at strategic points indicated. Voltages enclosed in squares are DC measurements, with no input signal applied to the board.

Readings enclosed in circles are signal level measurements, taken from an oscilloscope, with a signal of 10MHz and an amplitude of 30mV rms applied to the A input. This signal is suitable for checking both the 10MHz and 100MHz ranges of the counter, as it can be followed through the stages by even a relatively cheap oscilloscope.

To check the performance of prescalers, use an input signal which will allow the output of the prescaler to be observed on the oscilloscope. 100MHz, again at a level of 30mV rms, is a useful signal for checking prescalers. If no output is obtained from the prescaler, it may be possible to trace through it by decreasing the frequency of the test signal, but correct performance of the prescalers cannot be guaranteed much below 100MHz. An increase in the amplitude of the signal will be required.

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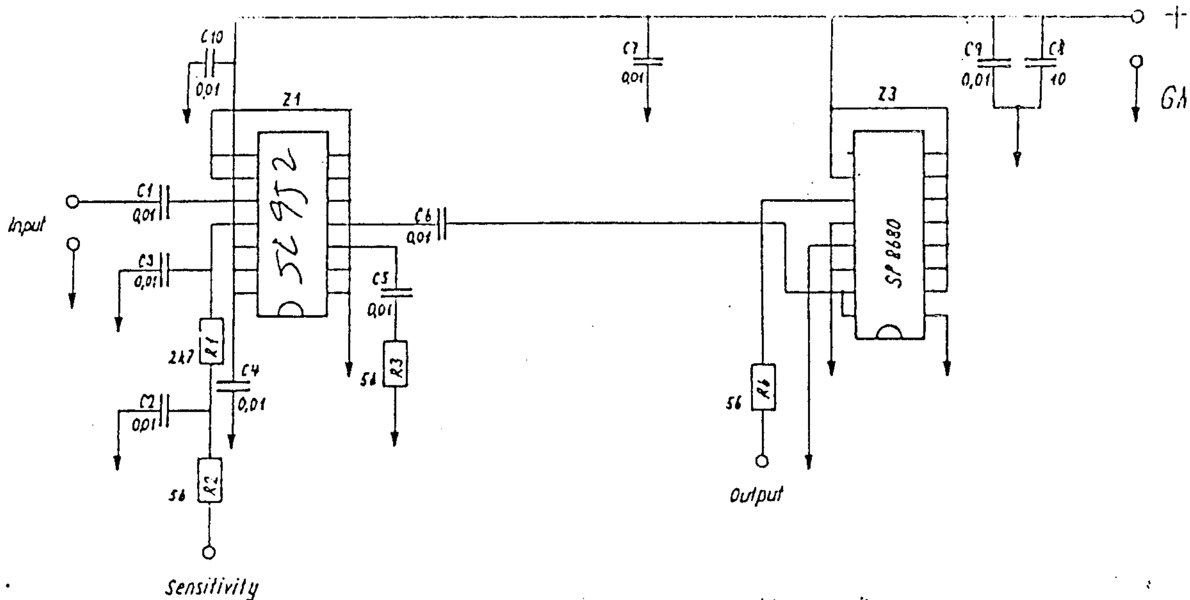
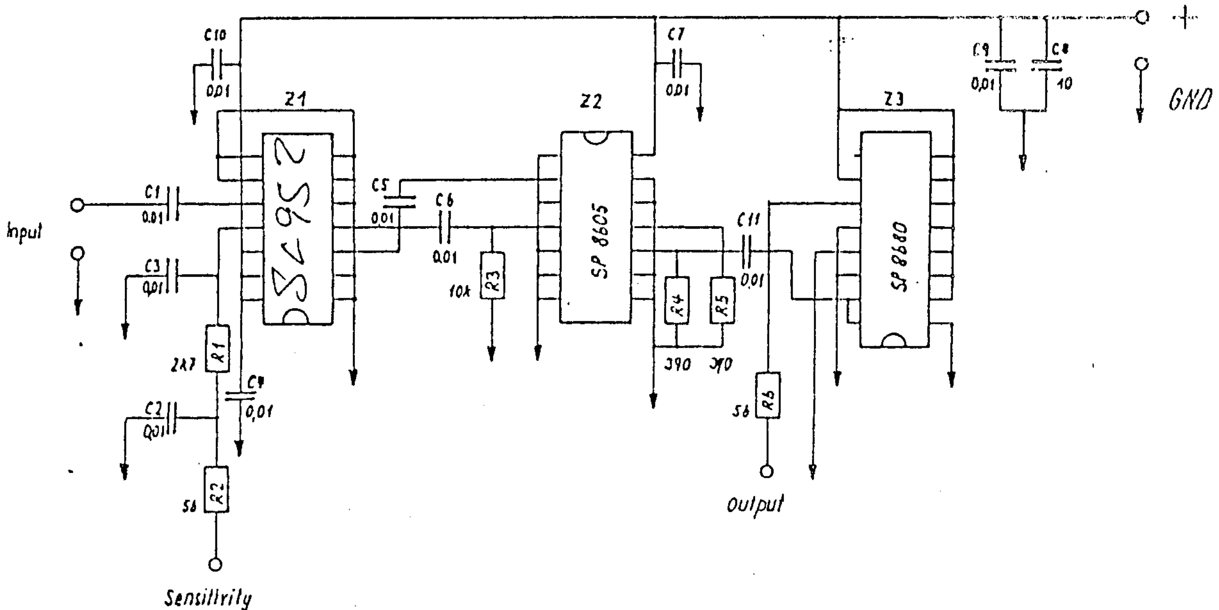


C1, C3, C4, C5, C6, C10: 0,01µF chip capacitor

REV	C.O.	DATE	BY

sabtronics INTERNATIONAL INC

DRN Qvinter	DATE 6.7.83	TOLERANCE ± .005 PSC 1000-3
CHK G S	DATE 8.7.83	NAME 600MHZ ./.10 PRESCALER
ENG P C	DATE 1.7.83	
SCALE	SHT OF	PART NO. B1810



C1, C3, C4, C5, C6, C10: 0,01µF chip capacitor

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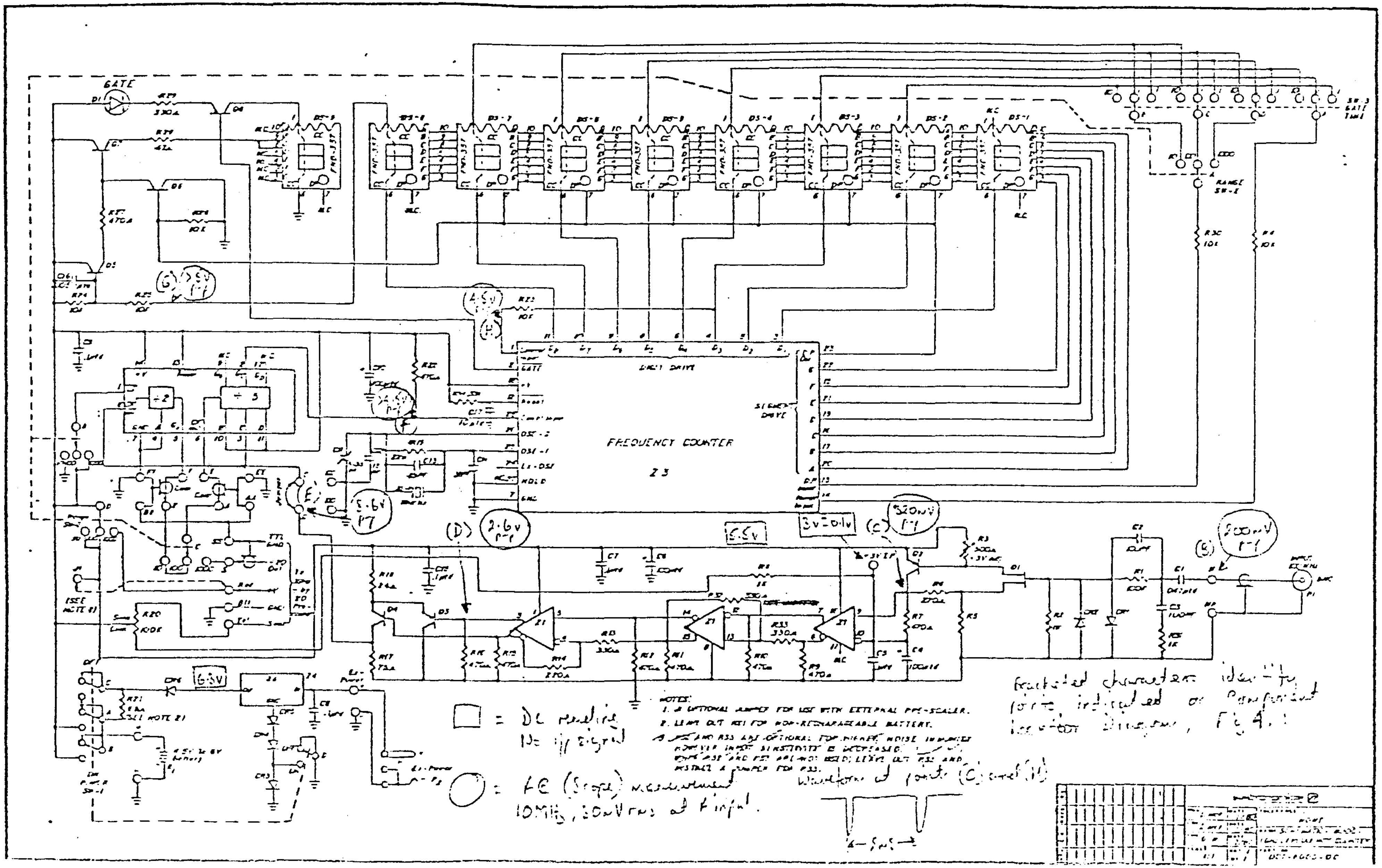
SECTION 6

COMPONENT SUBSTITUTION

There is not much to note on this score. Only one device has generally been affected by supply problems, and in this case an alternative device has been used in production.

The device concerned is the 2N5771, used for Q2, Q3 and Q4 of the Main Counter Board. It is quite common to find MPSH81 transistors in place of the original devices.

NOTE: the MPSH81 has a different pin out to the 2N5771, and therefore does not line up with the orientation shown on the PCB legend.


GATE
FREQUENCY COUNTER
Z3
DIGIT DRIVE
SEGMENT DRIVE
FND-357
RANGE SW-2
SW-3 GATE TIME
(D) 2.6v
(E) 5.6v
(F)
(G) 3.5v
(H) 4.5v
(C) 320mV
(B) 200mV
5.5v
6.3v
3v±0.1v
NOTES:
1. A OPTIONAL JUMPER FOR USE WITH EXTERNAL PRE-SCALER.
2. LEAVE OUT R21 FOR NON-RECHARGEABLE BATTERY.
□ = DC reading, No i/p signal
○ = AC (Scope) measurement 10MHz, 30mVrms at input.
Bracketed characters identify points indicated on Component Location Diagram, Fig 4.1
Waveform at points (C) and (D)