D.C. NANOVOLTMETER

TYPE 6045

H. Tinsley & Co. Ltd.

SCIENTIFIC INSTRUMENT MANUFACTURERS — MINISTRY OF DEFENCE 05-24 APPROVED COMPANY

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TYPE 6045

CONTENTS:

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D.C. NANOVOLTMETER TYPE 6045.

INTRODUCTION.

The Type 6045 is an extremely sensitive D.C. measuring instrument, designed for specialist application in the fields of calibration, scientific research and engineering. State of the art technology is used to ensure that extremely low levels may be measured with ease and convenience.

The equipment is all solid state and employs an input modulator, A.C. amplifier, and demodulator in the input amplifying stages. The techniques used allow overall negative feedback around the input amplifier, which gives a high input impedance and closely controlled gain.

The overall gain of the instrument is controlled by two negative feedback networks; that of the input amplifier and also the following amplifier stage.

The offset control is applied at the output of the second amplifier stage and this effectively increases the scale-length of the meter and allows small voltage changes to be measured in comparatively large levels.

The output of the amplifier is taken to an isolator, which can be used to drive a recorder, or enables the instrument to be used as the front end of a system.

OPERATION.

SWITCHING ON.

When the very sensitive ranges are to be used, first switch to a higher range, e.g., 3 microvolts, switch on, let the meter settle and then select the more sensitive range. This will save delay caused by the higher time constant of the low ranges and the wide dynamic range of the input amplifier.

RANGE.

There are 11 basic ranges and potentials from 1 mV down to a few hundred pico volts may be measured. The response time of the instrument and the input impedance vary with the range selected. The basic ranges are used in conjunction with the direct (Hi X1, Lo)input terminals.

SCALE

When voltages higher than 1 mV need to be measured, the scale switch should be set to $X10^3$ for up to 1V and $X10^6$ for higher than 1V. The attenuated input terminal (Hi$X10^3X10^6$)and the common or Lo terminal must be used.

FILTER/OFFSET

The instrument is normally operated with the filter switch in the position marked "filter min, offset O". When a measurement is being made from a noisy source, or the voltmeter is coupled to a recorder for long term drift measurements, then the filter switch may be set to "Filter Max" to achieve a reduction of the A.C. component of the input. The effective scale length of the instrument may be increased up to 10 times by using the offset. The plus and minus positions on the filter switch connect the offset to the amplifier in the polarity indicated. The ten turn dial is calibrated to read in percentage of full scale deflection up to 100%.

ZERO

This control is used to bring the input amplifier to zero, and should only be used with the input terminals short circuited by a clean, pure copper strap, which is used as an input reference. The zero control should not need adjustment in normal use.

BATTERY CHECK.

The on/off switch contains a check for each of the two internal batteries. If the voltage of either battery falls below 8V, the mains supply should be connected.

CHARGER.

The batteries will be charged automatically when the A.C. mains supply is connected, whether or not the instrument is switched on, and the charger indicator will be illuminated. When the charger is not in use, it is preferable to disconnect the mains lead from the instrument, thereby allowing the complete advantage of battery operation. The battery will be completely charged in 14 hours and will give about 60 hours of operation from a full charge.

INPUT TERMINALS

The direct input terminals have been designed for low thermal e.m.f. characteristics and ease of operation. The voltage applied to the direct input (Hi X 1) should not be allowed to exceed 10 mV in order to avoid unwanted thermo-electric effects. Connections should be made using clean, pure copper wire. If potentials greater than 1 mV are to be measured then the attenuator input terminal (Hi X 10^3) should be used in conjunction with the appropriate setting of the "scale" switch. The terminal marked "case" is a direct connection to the chassis of the instrument and is earthed when the mains is connected.

OUTPUT

The output is taken from the red and black sockets at the rear of the instrument. The output is isolated from the input and has a level of plus and minus 1V for full scale deflection and is capable of driving 1 mA. The amplifier gain is 1 volt divided by the range setting in volts. The white socket at the rear is connected to the case and is earthed when the mains is connected.

MEASURING NANOVOLTS.

When making measurements at this very low level, care must be exercised to minimise the effects of unwanted signals. These can arise principally from the following causes:

1. Noise
2. Thermal e.m.f.
3. Electric and magnetic fields
4. Ground Loops.

1. Noise. This is generated in all conductors, by thermal agitation of electrons. In a perfect conductor the noise voltage developed across the conductor is given by: $en = \sqrt{4KTRdF}$. From this equation, it appears that the noise may be minimised by reducing source impedance, cooling and limiting band width. In many cases only the latter is practical and this has the disadvantage of increasing the time necessary to resolve very low levels.

2. Thermal e.m.f. A potential arises at the junction of dissimilar conductors and even at the contact between two pieces of material which are nominally similar. All junctions should be kept at the same temperature and as close together as possible.

3. Electric and Magnetic Fields. The effects of these sources of unwanted signal can be minimised by keeping the area enclosed to a minimum by the circuit under test. Measurement leads should be twisted pairs and the whole circuit should be screened, if necessary, using high permeability substances such as mumetal.

4. Ground Loops. This source of unwanted signal is familiar even with normal signal levels. At Nanovolt levels even more care is necessary and all common connections should be made to a single point. The Type 6045 d.c. Nanovoltmeter is battery operated and so may be connected without contributing to the problem.

The Nanovoltmeter incorporates a low pass filter which may be switched in to minimise the effects of noise from the circuit under test, if measurement time permits.

Another useful feature is the offset control. This may be used to back off a potential from the circuit under test and so small changes may be measured more easily.

The zero control should not be used for this purpose. This control is for maintaining the amplifier's internal zero which should only be checked using a clean, pure copper strap across the input terminals, as a zero reference.

CIRCUIT DESCRIPTION.

The low thermal e.m.f. terminals are connected directly to the input unit via matched copper conductors. The attenuated input may be switched across the direct input by the scale switch, which connects an attenuator of either one thousand or one million to the input.

The input unit operates as a modulator whose output is an A.C. signal proportional to the d.c. input. The A.C. is taken to the input of an A.C. amplifier, on p.c.b.3, whose output is coupled by means of a transformer to the demodulator on p.c.b.1. The demodulator consists of IC1 to IC4 and is an active bridge driven in synchronism with the modulator. The amplified and restored d.c. signal is taken to the input of IC5 and a d.c. potential from the front panel zero control is brought via pin 3 to the summing junction of IC5.

The signal at the output of IC5 is further amplified by IC6. The feedback networks of IC5 and IC6 control the gain and phase shift of the input amplifier. The output of IC6 is connected via pin 4 to the first switched feedback network operated by the range switch. This network controls the gain of the input amplifier. A resistor-capacitor circuit in the feedback network limits the band-width of the amplifier to give the required response on each range.

The output of IC6 is also taken to the next amplifier stage IC7. This is a stable d.c. amplifier whose gain is controlled by the second switched feedback network operated by the range switch. Three capacitors are included in this network to give a response appropriate to the range selected and one of them is operated by the filter switch and reduces the low pass response by approximately ten times.

The output of IC7 is taken via the overall gain adjuster, P6, to the input of IC8a. A potential derived from the offset control on the front panel is taken via 7 to the summing junction of IC8a. The offset voltage is switched by the filter switch. IC8b is an invertor and buffer stage, whose output is taken to the meter and the isolator.

The modulator and demodulator drive functions are provided by the circuit including IC9, IC10, T1, T2 and T3. IC9 is a stable square wave generator which drives a shaping network using T1, T2 and T3. The signals at pins 9 and 10 are used to operate the modular circuit. The demodulator drive is taken from the output of IC10a and IC10b.

IC11 is a quad amplifier and is connected as four voltage regulators to provide the stable supplies needed for the d.c. amplifier circuits. D3 is a band gap device and is used as the basic reference voltage.

The amplifier output is at pin 8 of p.c.b.1, this is connected via P1 and R1 on p.c.b.2 and the on/off switch to the meter. The meter is short-circuited when the instrument is switched off.

The isolator, output stage and battery charger are contained on p.c.b.2. IC2 is a multi-vibrator which drives a power switching stage whose output is connected to a transformer, Tr2. The current in the secondary circuit of Tr2 is rectified and smoothed and provides the power for the output stage. Tr2 also drives the synchronous demodulator IC3. The signal from the output of the main amplifier is connected to pin 1 of p.c.b.2. The d.c. at pin 1 is modulated by IC1, passed through transformer Tr1 and demodulated by IC3. IC4 is a low pass filter and buffer stage and its output is taken to the output sockets at the rear panel of the instrument.

The output of Tr3 is rectified and taken via D11 and R13 to the instrument batteries. A further output via R14 goes to the front panel charging indicator.

The batteries can give high current and so each is fused at 100 mA and the mains input is fused at 100 mA anti-surge.

A terminal is provided at the front and rear of the instrument which is connected to the case.

ADJUSTMENT PROCEDURE.

1. ACCESS.

Remove the screw holding the top cover in place and slide off the top cover. Remove the six screws holding on the switch box lid and lift it off. p.c.b.1 containing the main amplifier and drive circuits may be moved upwards to gain access to the components, if necessary.

Do not, UNDER ANY CIRCUMSTANCES, interfere with the input unit, which is mounted in foam plastic at the right hand side of the switch box. If this unit is suspected of being faulty then the instrument must be returned to the manufacturer for servicing.

2. POWER SUPPLY.

Check the voltage at pin 11 of p.c.b.1, referred to 13, using a digital voltmeter with an accuracy of 0.1%. The reading should be about minus 6.2V. Check the voltage at pin 12 and adjust P9, if necessary, until the numerical value is the same as pin 11, the polarity however is positive. Pin 19 should be about plus 6.2 V and pin 20 at about minus 6.2V.

3. INPUT MODULATOR

Switch to the 100 nV range. If the modulator is correctly adjusted, one full turn of the front panel zero control should give a deflection of about 10 nanovolts. If the deflection is much greater than this the modulator should be adjusted as follows:

Turn the front panel zero control until the deflection on the meter is about half scale. Make very small adjustments of P7 and P8 until the meter reads a minimum. If the adjustment of P7 and P8 is very far from correct then the following procedure should be adopted. Disconnect the wire from 4 on p.c.b.1. Connect a function generator to the input terminals, via an attenuator, to give a level of about 100 microvolts. The frequency range should be 0.1 Hz to 10 KHz with a sine wave signal. Connect an oscilloscope to the junction of R1 and R2 and trigger it externally from the junction of R33 and R34. Set the time base to 1 mS/cm and sensitivity to 2 V/cm. With the generator set to about 2 KHz, adjust P7 and P8 for maximum constant amplitude, without any steps in the response. Sweep the frequency down to 0.1 Hz and check that maximum amplitude is maintained without discontinuities. Reconnect the wire to pin 4 of p.c.b.1. Keep filter switch set to 'Filter Min O'.

4. ZERO

Connect a clean, pure copper strap between the input terminals and set the front panel zero control to the middle of its travel. With the instrument switched off, check the mechanical zero on the meter. Switch on and set the range to 100 nV. Adjust P1 for approximately zero. Switch to the 1 mV range and adjust P4 for zero on the meter. Repeat if necessary making the final zero adjustment on the lowest range using the front panel zero control.

5. SENSITIVITY

Connect a DVM to the output terminals at the rear of the instrument, set to the 1 V range. Switch the nanovoltmeter to the 1 mV range and adjust P3 on p.c.b.2 for zero on the DVM. Apply an input of exactly 1 mV and adjust P2 on p.c.b.1 for 1.000 volts out. Adjust P1 on p.c.b.2 for f.s.d. on the meter. Connect the input strap and switch to the 1 mV range. Switch the 'offset' switch to 'Filter Min offset positive'.

Turn the offset control to read '100', i.e., exactly one revolution. Adjust P3 on p.c.b.1 to read 1.000 V on the DVM. Switch to offset negative and check that the DVM reads minus 1.000 V. A small adjustment of P9 will correct any discrepancy.

Remove the DVM. Set the range to 10 microvolts and connect a 100 K resistor between the input terminals. Adjust P5 and P6 for zero, making the same amount of adjustment on each.

Replace the switch box lid. Reconnect the input short circuit. Set the range to 100 nV and connect a lead from the black output terminal to the input short circuit. Adjust P2 on p.c.b.2 for minimum. Replace the cover on the instrument.

Type 6045 Nanovoltmeter Parts List.

Mainframe.

RI	Resistor	4MO	0.25%	IOOppm
R2	Resistor	4KO	0.25%	IOOppm
R3	Resistor	4RO	0.25%	IOOppm
R4	Resistor	IOOK	2%	Metal Film
R5	Resistor	IOOR	2%	Metal Film
R6	Resistor	3KO	0.I%	50ppm
R7	Resistor	IOK	0.I%	50ppm
R8	Resistor	30K	0.I%	50ppm
R9	Resistor	IOOK	0.I%	50ppm
RIO	Resistor	300K	0.I%	50ppm
RII	Resistor	IMO	0.I%	50ppm
RI2	Resistor	IOK	0.I%	50ppm
RI3	Resistor	30K	0.I%	50ppm
RI4	Resistor	IOOK	0.I%	50ppm
RI5	Resistor	300K	0.I%	50ppm
RI6	Resistor	IMO	0.I%	50ppm
RI7	Resistor	3MO	0.I%	50ppm
RI8	Resistor	20K	I%	Metal Film
RI9	Resistor	20K	I%	Metal Film

PI	Potentiometer	IOOK	Ten turn
P2	Potentiometer	25K	Ten turn

CI	Capacitor	2.2uF	IO%	63v
C2	Capacitor	4u7	IO%	63v
C3	Capacitor	IuF	IO%	63v
C4	Capacitor	IOuF	IO%	63v

FI	Fuse	200mA	
F2	Fuse	200mA	
F3	Fuse	IOOmA	Anti surge

Printed Circuit Board I.

RI	Resistor	4K7	2%	Metal Film
R2	Resistor	220K	2%	Metal Film
R3	Resistor	470R	2%	Metal Film
R4	Resistor	IM	2%	Metal Film
R5	Resistor	470K	2%	Metal Film
R6	Resistor	2K2	2%	Metal Film
R7	Resistor	IOOR	2%	Metal Film
R8	Resistor	IOOK	2%	Metal Film
R9	Resistor	IOOK	2%	Metal Film
RIO	Resistor	IM	2%	Metal Film
RII	Resistor	IOM	5%	
RI2	Resistor	IOOR	2%	Metal Film
RI3	Resistor	IOK	2%	Metal Film
RI4	Resistor	IOK	2%	Metal Film
RI5	Resistor	IOOR	2%	Metal Film
RI6	Resistor	I20K	2%	Metal Film
RI7	Resistor	IK	2%	Metal Film
RI8	Resistor	220K	2%	Metal Film
RI9	Resistor	270K	2%	Metal Film

R20	Resistor	IM	2%	Metal Film
R22	Resistor	IOOK	2%	Metal Film
R23	Resistor	IOOK	2%	Metal Film
R24	Resistor	3K9	2%	Metal Film
R25	Resistor	IOM	5%	
R26	Resistor	IOM	5%	
R27	Resistor	8K2	2%	Metal Film
R28	Resistor	22K	2%	Metal Film
R29	Resistor	22K	2%	Metal Film
R30	Resistor	270K	2%	Metal Film
R3I	Resistor	220K	2%	Metal Film
R32	Resistor	270K	2%	Metal Film
R33	Resistor	IM	2%	Metal Film
R34	Resistor	4K7	2%	Metal Film
R35	Resistor	4K7	2%	Metal Film
R36	Resistor	2K2	2%	Metal Film
R37	Resistor	2K2	2%	Metal Film
R38	Resistor	47K	2%	Metal Film
R39	Resistor	IOK	2%	Metal Film
R40	Resistor	IOM	5%	
R4I	Resistor	47K	2%	Metal Film
R42	Resistor	IOK	2%	Metal Film
R43	Resistor	IOM	5%	
R44	Resistor	IOK	2%	Metal Film
R45	Resistor	47K	2%	Metal Film
R46	Resistor	IOK	2%	Metal Film
R47	Resistor	47K	2%	Metal Film
R48	Resistor	IOK	2%	Metal Film
R49	Resistor	39K	2%	Metal Film
R50	Resistor	IOK	2%	Metal Film
R5I	Resistor	39K	2%	Metal Film
R52	Resistor	3K3	2%	Metal Film

PI	Potentiometer	IOOK
P2	Potentiometer	50K
P3	Potentiometer	50K
P4	Potentiometer	IOOK
P5	Potentiometer	5K
P6	Potentiometer	5K
P7	Potentiometer	IOOK
P8	Potentiometer	IOOK
P9	Potentiometer	5K

CI	Capacitor	2u2	IO%	63v
C2	Capacitor	0.IuF	IO%	63v
C3	Capacitor	0.IuF	IO%	63v
C4	Capacitor	0.47	IO%	63v
C5	Capacitor	0.0I	IO%	63v
C6	Capacitor	InF	IO%	63v
C7	Capacitor	IuF	IO%	63v
C8	Capacitor	0.IuF	IO%	63v
C9	Capacitor	0.IuF	IO%	63v
CIO	Capacitor	IuF	IO%	63v
CII	Capacitor	0.IuF	IO%	63v
CI2	Capacitor	IuF	IO%	63v
CI3	Capacitor	0.IuF	20%	30v
CI4	Capacitor	0.IuF	20%	30v

CI5	Capacitor	0.047	I0%	63v
CI6	Capacitor	0.047	I0%	63v
CI7	Capacitor	2n2	I%	63v
CI8	Capacitor	4n7	I%	63v
CI9	Capacitor	0.047	I0%	63v
C20	Capacitor	0.047	I0%	63v
C2I	Capacitor	0.IuF	20%	30v
C22	Capacitor	47uF	20%	I0v
C23	Capacitor	47uF	20%	I0v
C24	Capacitor	47uF	20%	I0v
C25	Capacitor	47uF	20%	I0v

DI	Diode	IN4I48
D2	Diode	IN4I48
D3	Diode	ZN423
TI	Transistor	BCY7I
T2	Transistor	2N2484
T3	Transistor	2N2484
ICI	Integrated Circuit	HIIFI
IC2	Integrated Circuit	HIIFI
IC3	Integrated Circuit	HIIFI
IC4	Integrated Circuit	HIIFI
IC5	Integrated Circuit	ICL7650
IC6	Integrated Circuit	TL06I
IC7	Integrated Circuit	ICL7650
IC8	Integrated Circuit	TL062
IC9	Integrated Circuit	CA3I30
ICIO	Integrated Circuit	LM393
ICII	Integrated Circuit	LM324

Printed Circuit Board 2.

RI	Resistor	3K3	2%	Metal Film
R2	Resistor	22K	2%	Metal Film
R3	Resistor	22K	2%	Metal Film
R4	Resistor	22K	2%	Metal Film
R5	Resistor	22K	2%	Metal Film
R6	Resistor	47K	2%	Metal Film
R7	Resistor	I00K	2%	Metal Film
R8	Resistor	I00K	2%	Metal Film
R9	Resistor	390K	5%	
RIO	Resistor	I00K	2%	Metal Film
RII	Resistor	390K	5%	
RI2	Resistor	47K	2%	Metal Film
RI3	Resistor	I50R	5%	2.5W Wire Wound
RI4	Resistor	4K7	2%	Metal Film

PI	Potentiometer	IK
P2	Potentiometer	I00K
P3	Potentiometer	I0K

CI	Capacitor	0.022	20%	I00v
C2	Capacitor	220uF		I0v
C3	Capacitor	220uF		I0v
C4	Capacitor	2u2	20%	63v

C5	Capacitor	2u2	20%	63v
C6	Capacitor	IOOpF	5%	63v
C7	Capacitor	IOOpF	I%	630v
C8	Capacitor	470uF		6.3v
C9	Capacitor	470uF		6.3v
CIO	Capacitor	0.47	IO%	63v
CII	Capacitor	0.I	20%	IOOv
CI2	Capacitor	0.0I	20%	IOOv
CI3	Capacitor	IOOOuF		40v

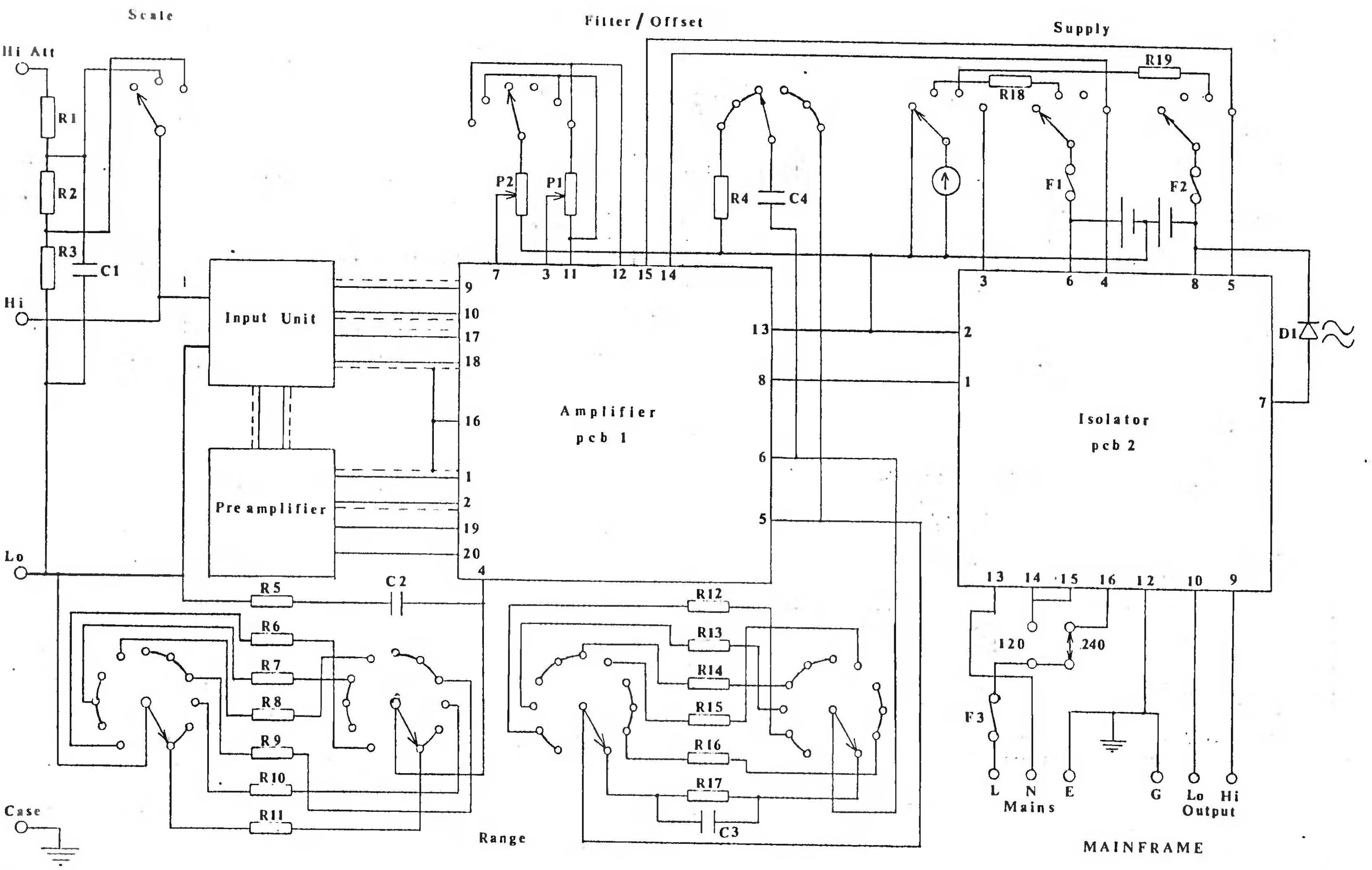
DI	Diode	IN4I48
D2	Diode	IN4I48
D3	Diode	IN4I48
D4	Diode	BZX79C2V4
D5	Diode	IN4I48
D6	Diode	IN4I48
D7	Diode	IN4I48
D8	Diode	IN4I48
D9	Diode	IN4I48
DIO	Diode	IN4I48
DII	Diode	IN400I
DI2	Diode Bridge	IA

TI	Transistor	2N2484
T2	Transistor	2N2484
T3	Transistor	2N3962
T4	Transistor	2N3962

ICI	Integrated Circuit	CD4066BCN
IC2	Integrated Circuit	CD4047BCN
IC3	Integrated Circuit	CD4066BCN
IC4	Integrated Circuit	CA3I40E

Printed Circuit Board 3.

RI	Resistor	270K	2%	Metal Film
R2	Resistor	3K9	2%	Metal Film
R3	Resistor	3K9	2%	Metal Film
R4	Resistor	5K6	2%	Metal Film
R5	Resistor	27R	2%	Metal Film
R6	Resistor	270R	2%	Metal Film
R7	Resistor	33M	Thick Film	
R8	Resistor	470R	2%	Metal Film
PI	Potentiometer	200R		
CI	Capacitor	0.IuF	IO%	63v
C2	Capacitor	0.047	IO%	63v
C3	Capacitor	InF	IO%	63v
C4	Capacitor	0.IuF	20%	30v
C5	Capacitor	0.IuF	20%	30v
TI	Transistor	2N6483		
ICI	Integrated Circuit	LM725		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Hi Att
R1
R2
R3
C1
Hi
Lo
Case
Input Unit
Preamplifier
Filter / Offset
P2
P1
R4
C4
Amplifier
pcb 1
Supply
R19
R18
F1
F2
D1
Isolator
pcb 2
R5
C2
R6
R7
R8
R9
R10
R11
Range
R12
R13
R14
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R17
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F3
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N
E
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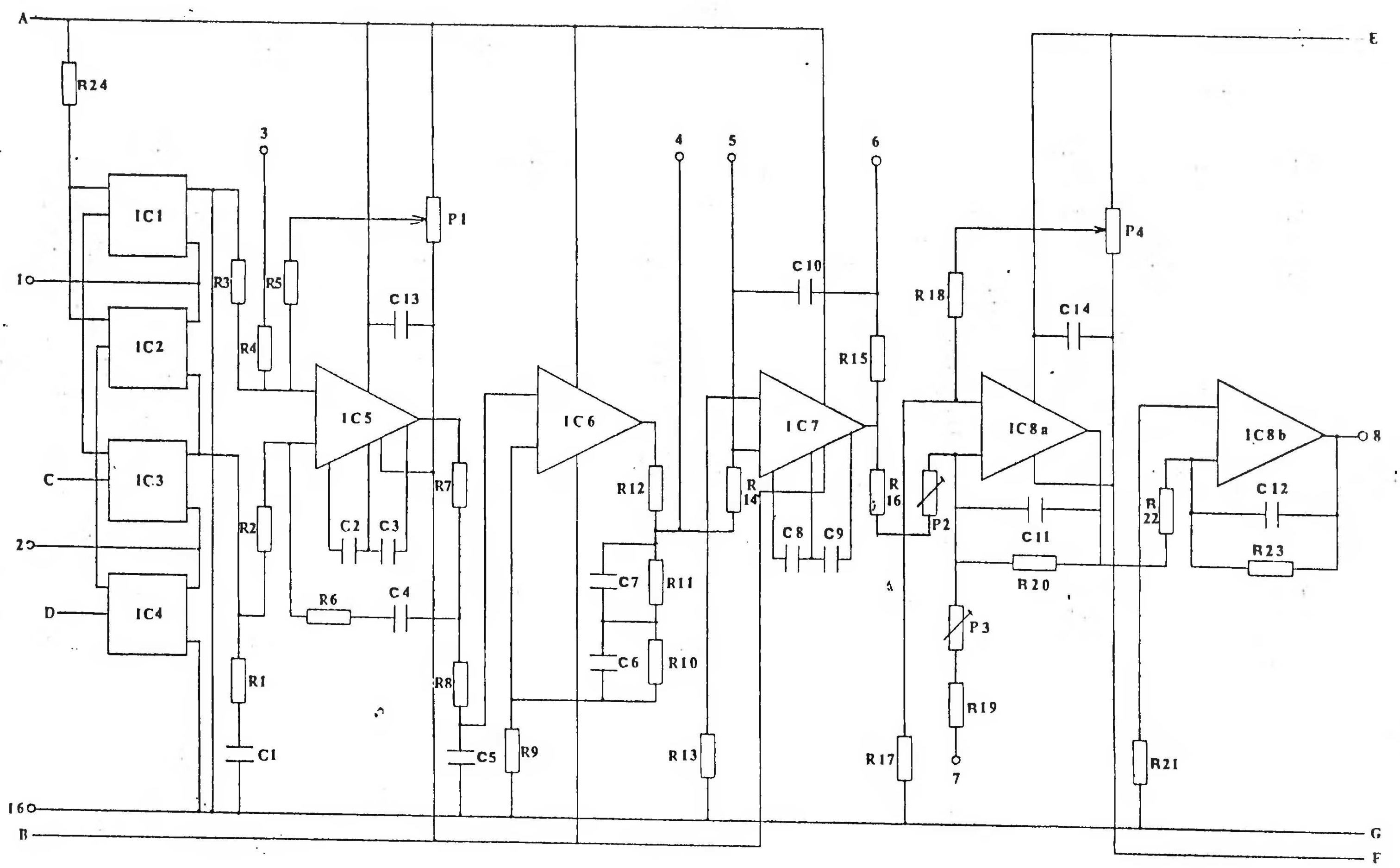
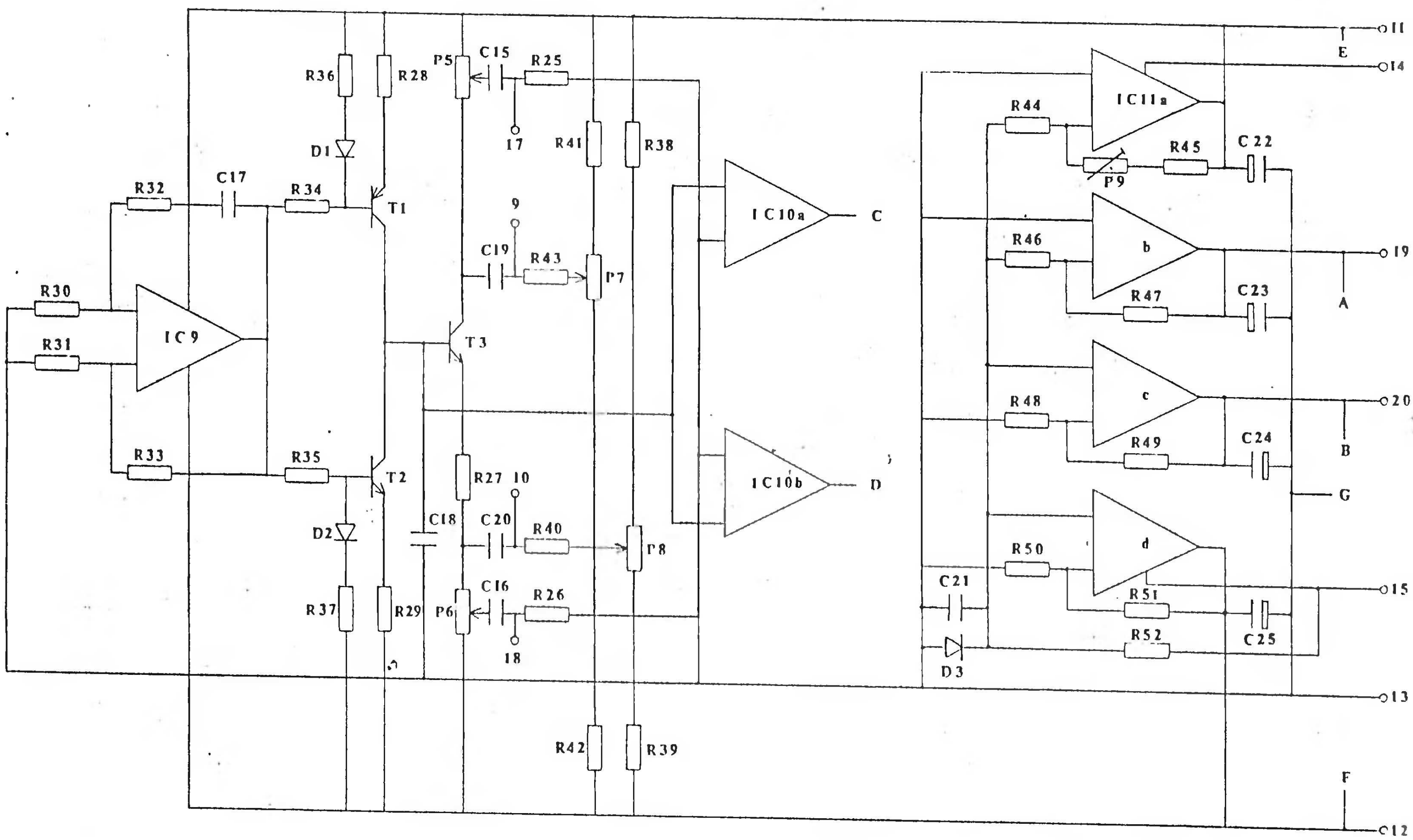
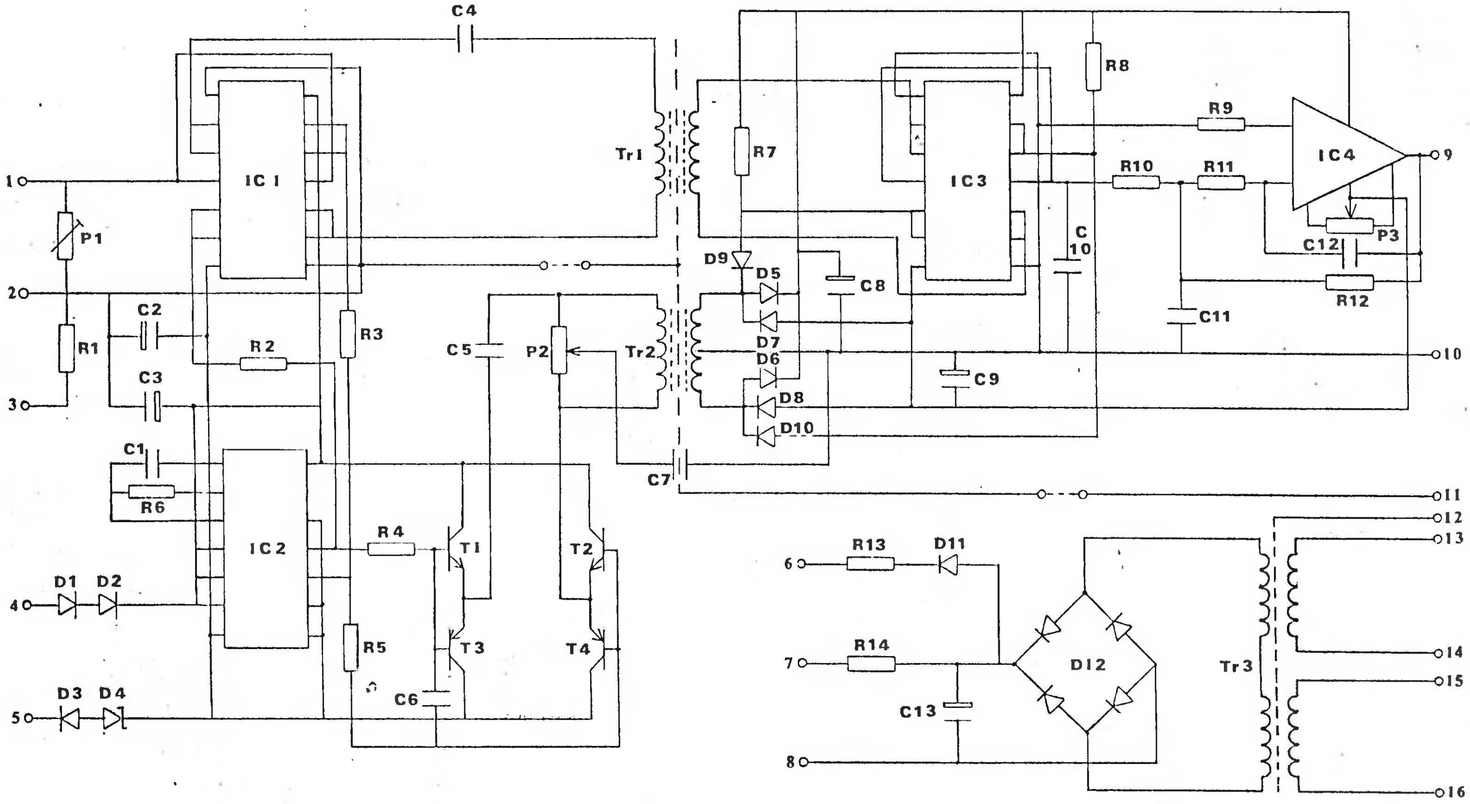
G
Lo
Hi
Output
MAINFRAME



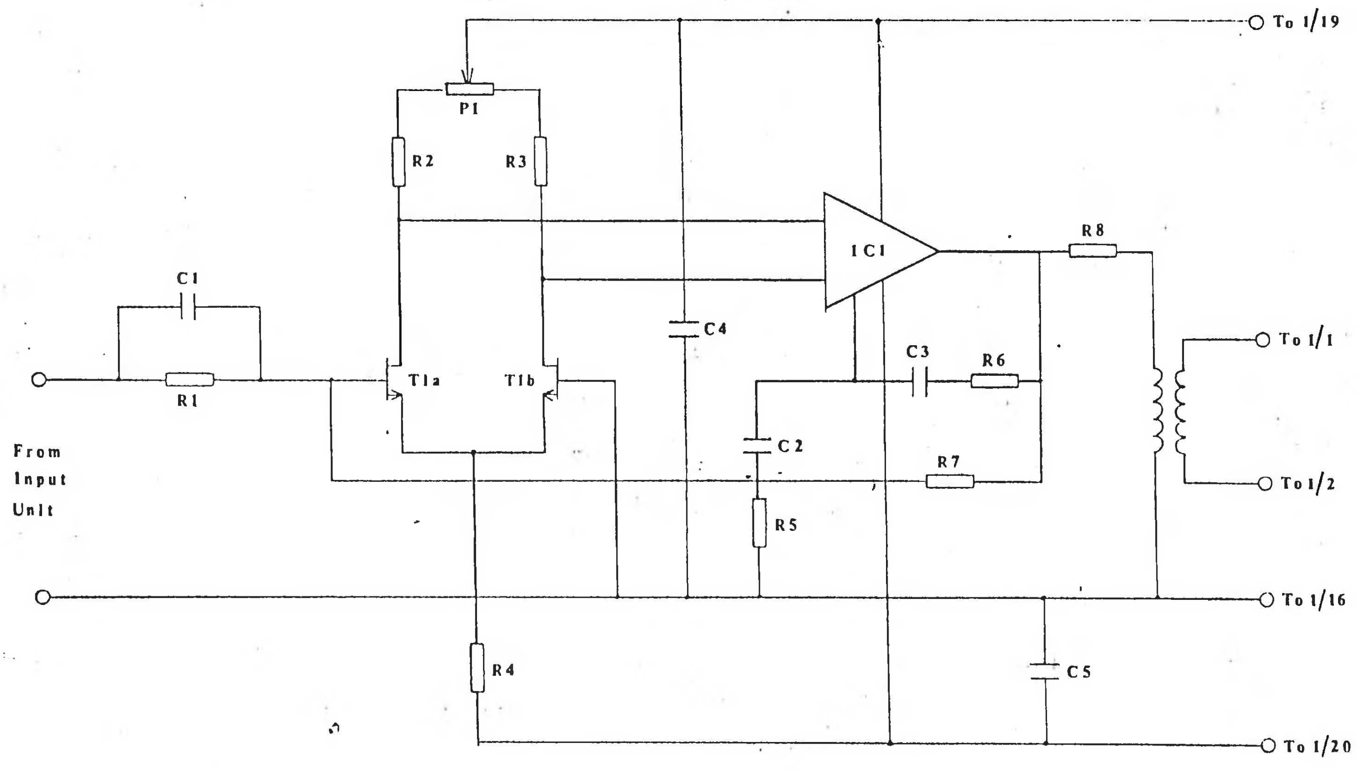
AMPLIFIER PCB 1



REGULATOR AND DRIVE PCB I



ISOLATOR AND BATTERY CHARGER PCB 2



PREAMPLIFIER PCB 3