LEAFLET BC.53 5.77

RADFORD

TECHNICAL INSTRUCTIONS INSTALLATION AND ADVANCED MAINTENANCE

HIGH SENSITIVITY AUDIO VOLTMETERS AND NOISEMETERS

1. GENERAL

The instrument is despatched from the factory fitted with its internal battery connected and ready for use. A description of the controls functions and facilities is described below, followed by operating details and maintenance and calibration procedures. This leaflet should be read in conjunction with the sales leaflet A53 which gives details of the instruments not repeated here.

2. CONTROLS, FUNCTIONS AND FACILITIES

2.1 Input Socket

The input impedance of the instrument is 1M ohm on all the measuring ranges except the —90db and —100db ranges where the impedance falls to approximately 820k ohms and 600k ohms respectively.

2.2 D.C. Output Socket (HSV2, ANM2 and ANM3 only)

This socket provides a d.c. output proportional to the meter reading. The instrument is calibrated such that 1.00V D.C. appears at this outlet when 1.00V A.C. is fed into the voltmeter on the OdBv range. Connection of a digital voltmeter on its 1 volt range will therefore provide a useful and precise alternative readout. 1.00V D.C. output is available on all input ranges corresponding to OdBv.

2.3 Signal Output Socket

This socket permits inspection of the signal waveform prior to the meter amplifier. An output of 1 volt A.C. corresponds to f.s.d. (OdBv). The output source resistance has been chosen to be relatively high (2k7 ohms) in order that connection of a low impedance does not affect the accuracy of the meter reading.

2.4 Input Range Switch

By suitably combining the gain of the measuring amplifier and the attenuation of the input attenuator, 16 measuring ranges are provided. On some ranges the residual noise with the input short circuited will just be apparent e.g. on the 10μV range.

2.5 Battery Check Switch

Depression of this switch connects the meter to indicate the on-load battery condition. The batteries should be replaced when the indication is outside the green area.

2.6 Noise Check Switch

This switch disconnects the input socket and short circuits the input of the instrument itself to ground. This enables the optimum position of the instrument in relation to external hum fields to be located or unsuitable connections in the measurement set-up to be detected by inspection of spurious signals at the output socket. (See 3.1 below)

2.7 External Weighting Switch

A weighting network of any desired characteristic may be inserted into the signal path of both the voltmeter and noisemeter. A 5-way DIN socket is mounted on the rear panel and provides the input signal at 100mV level for the rated input of the range selected, at a source resistance of 1k ohm. The return from an external filter is fed to a buffer amplifier providing a 1M ohm input resistance. The DIN socket also provides a + and —9 volt supply from the internal batteries to energise active filter networks. On the ANM3 this switch is located below the DIN socket on the rear panel.

2.8 Weighting Selector Switches

Four weighting characteristics may be selected on the Audio Noisemeters. Curves of the four frequency response characteristics are shown in the A53 sales leaflet.

2.9 Quasi-peak/r.m.s. Selector Switch (ANM3 only)

This switch selects the meter drive circuit. In the OUT position the instrument indicates true r.m.s. values on all wave forms. In the IN position the instrument is peak sensing but calibrated to read r.m.s. values on a sine wave. The pulse response of the circuit conforms with DIN 45 405 – Noise meter for Electro-acoustic Wideband circuits para 3.5.1 (Dynamic properties, Peak Value Indication).

3. OPERATION

3.1 Setting Up

It is important when using a system with an overall gain of up to 100dB that great care is taken both in the placement of the instrument in the laboratory and in the earthing layout of the measuring set up.

The instrument should be placed at a suitable distance from mains operated equipment such that the magnetic leakage field from the transformer does not induce hum in the low level circuitry of the voltmeter. Use of the 'Noise Check' button with the voltmeter's A.C. output connected to an oscilloscope will enable such induction to be seen.

The arrangement of earthing will also be found to be important when measuring at low levels. There are two conditions which may lead to erroneous readings. The first is when an earth loop exists in the measuring set up i.e. when more than one piece of apparatus is connected to a mains

(continued on back page)

DIAGRAMS

FIG. 1 LAYOUT UNDERSIDE VIEW. Voltmeters and noisemeters.

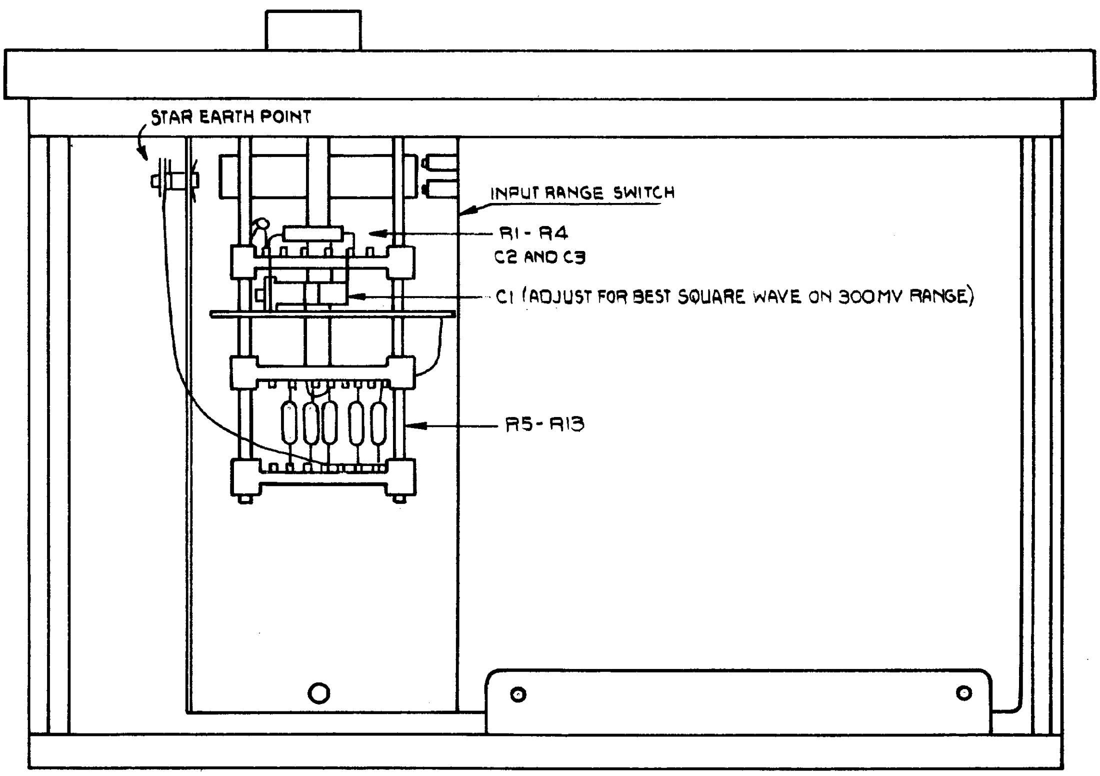


FIG. 2 PLAN VIEW. Voltmeters and noisemeters except ANM3.

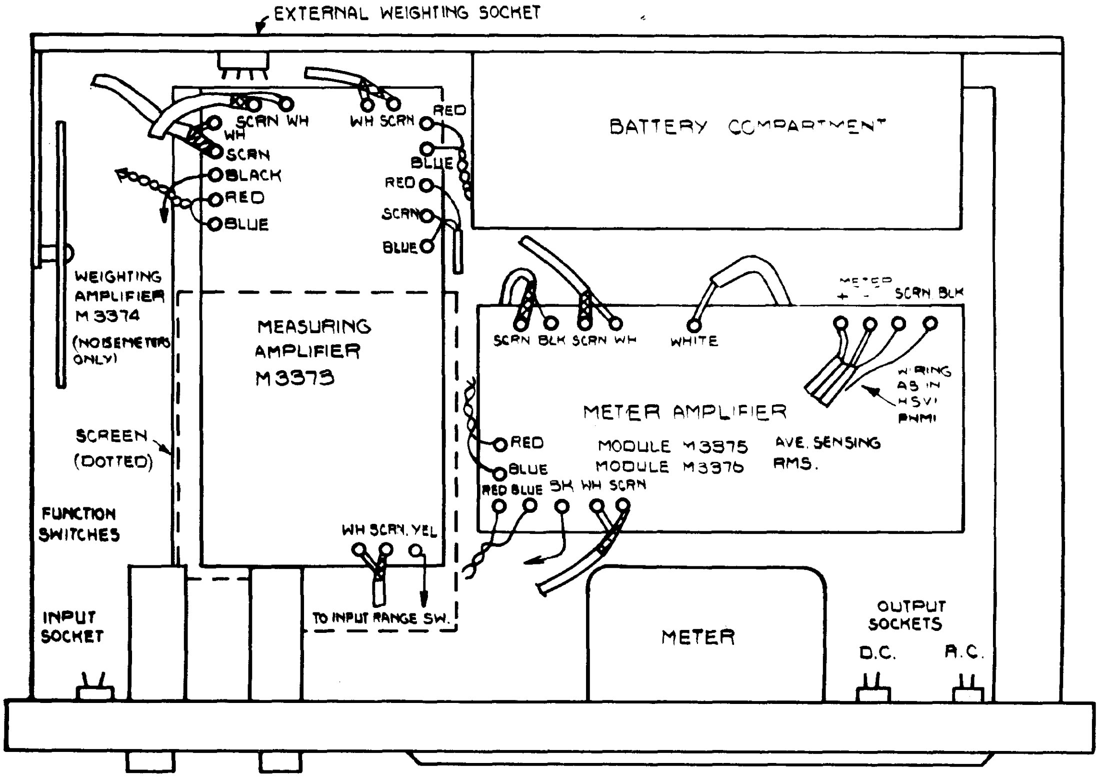
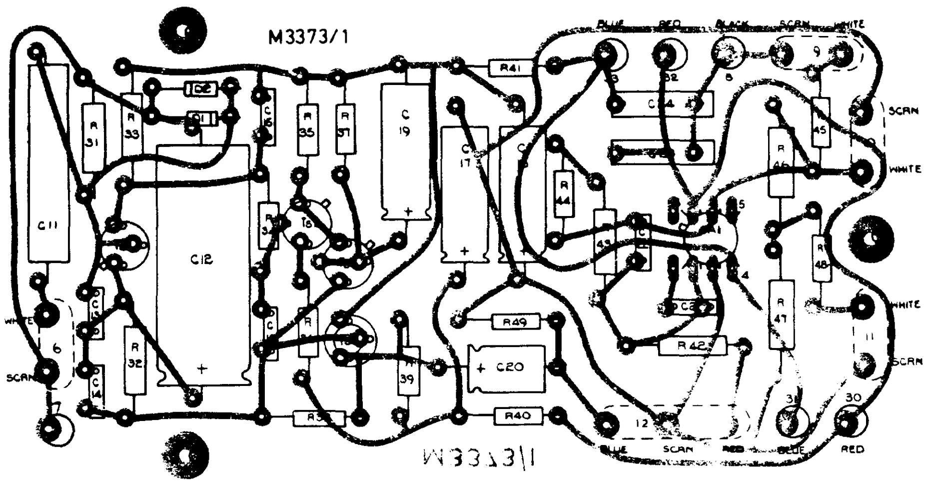
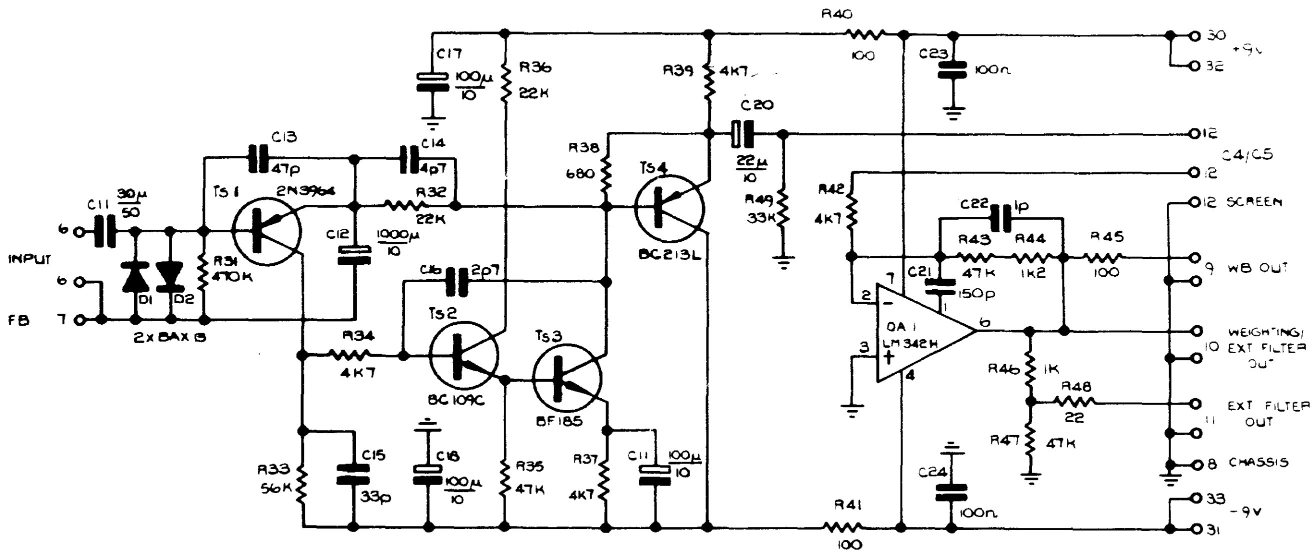


FIG. 3 PLAN VIEW. ANM3 only.

FIG. 4 MEASURING AMPLIFIER MODULE M3373.

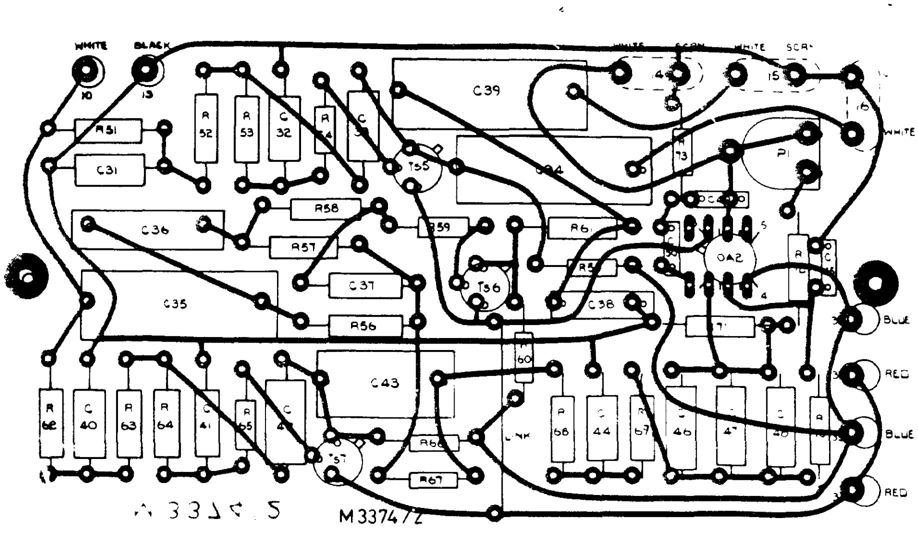


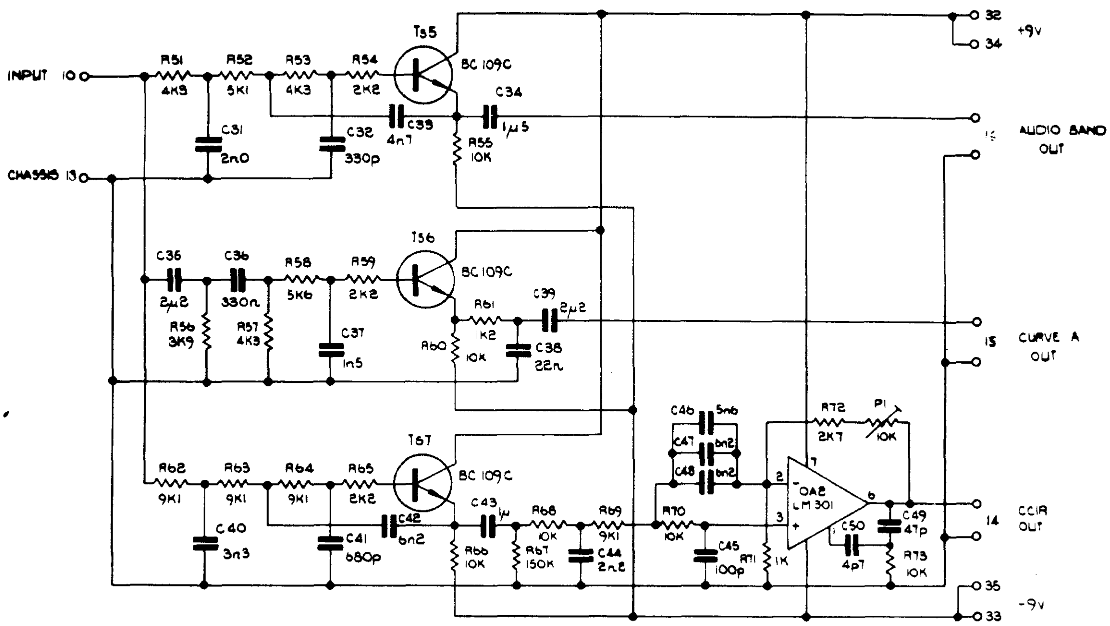


R31	MO	0.5W	470k	2%
R32	MO	0.5W	22k	2%
R33	MO	0.5W	56k	2%
R34	CF	0.25W	4k7	5%
R35	CF	0.25W	47k	5%
R36	CF	0.25W	22k	5%
R37	CF	0.25W	4k7	5%
R38	CF	0.25W	680R	5%
R39	See Text 6.1			
R40	CF	0.25W	100R	5%
R41	CF	0.25W	100R	5%
R42	MO	0.5W	4k7	2%
R43	MO	0.5W	47k	2%
R44	CF	0.25W	1k2	5%
R45	CF	0.25W	100R	5%
R46	MO	0.5W	1k	2%
R47	MO	0.5W	47k	2%
R48	CF	0.25W	22R	5%
R49	CF	0.25W	33k	5%

C11	E (REV.)	30µF	50V
C12	E	1000µF	10V
C13	CR	47pF	63V
C14	CR	4.7pF	63V
C15	CR	33pF	63V
C16	CR	2.7pF	63V
C17	E	100µF	10V
C18	E	100µF	10V
C19	E	100µF	10V
C20	E	22µF	10V
C21	CR	150pF	63V
C22	CR	A.O.T.	63V
C23	PR	0.1µF	100V
C24	PR	0.1µF	100V
TS1	2N3964		
TS2	BC109C		
TS3	BF185		
TS4	BC213L		
D1	BAX13		
D2	BAX13		
OA1	LM318		

FIG. 5 WEIGHTING AMPLIFIER MODULE M3374. Noisemeters only.





R51	MO	0.5W	4k3	2%	C31	PN	2000pF	100V	1%
R52	MO	0.5W	5k1	2%	C32	PN	330pF	100V	1%
R53	MO	0.5W	4k3	2%	C33	PN	4700pF	100V	1%
R54	CF	0.25W	2k2	5%	C34	PR	1.5µF	100V	10%
R55	CF	0.25W	10k	5%	C35	PR	2.2µF	100V	10%
R56	MO	0.5W	3k9	2%	C36	PR	0.33µF	100V	10%
R57	MO	0.5W	4k3	2%	C37	PN	1500pF	100V	1%
R58	MO	0.5W	5k6	2%	C38	PR	0.022µF	100V	10%
R59	CF	0.25W	2k2	5%	C39	PR	2.2µF	100V	10%
R60	CF	0.25W	10k	5%	C40	PN	3300pF	100V	1%
R61	MO	0.5W	1k2	2%	C41	PN	680pF	100V	1%
R62	MO	0.5W	9k1	2%	C42	PN	6200pF	100V	1%
R63	MO	0.5W	9k1	2%	C43	PR	1µF	100V	10%
R64	MO	0.5W	9k1	2%	C44	PN	2200pF	100V	1%
R65	CF	0.25W	2k2	5%	C45	CR	100pF	63V	
R66	CF	0.25W	10k	5%	C46	PN	5600pF	100V	1%
R67	CF	0.25W	150k	5%	C47	PN	6200pF	100V	1%
R68	MO	0.5W	10k	2%	C48	PN	6200pF	100V	1%
R69	MO	0.5W	9k1	2%	C49	CR	47pF	63V	
R70	MO	0.5W	10k	2%	C50	CR	4.7pF	63V	
R71	MO	0.5W	1k	2%					
R72	MO	0.5W	2k7	2%	TS5	ZTX109C		OA2	LM301
R73	CF	0.25W	10k	5%	TS6	ZTX109C			
P1	HORIZONTAL SKELETON PRESET		10k		TS7	ZTX109C			

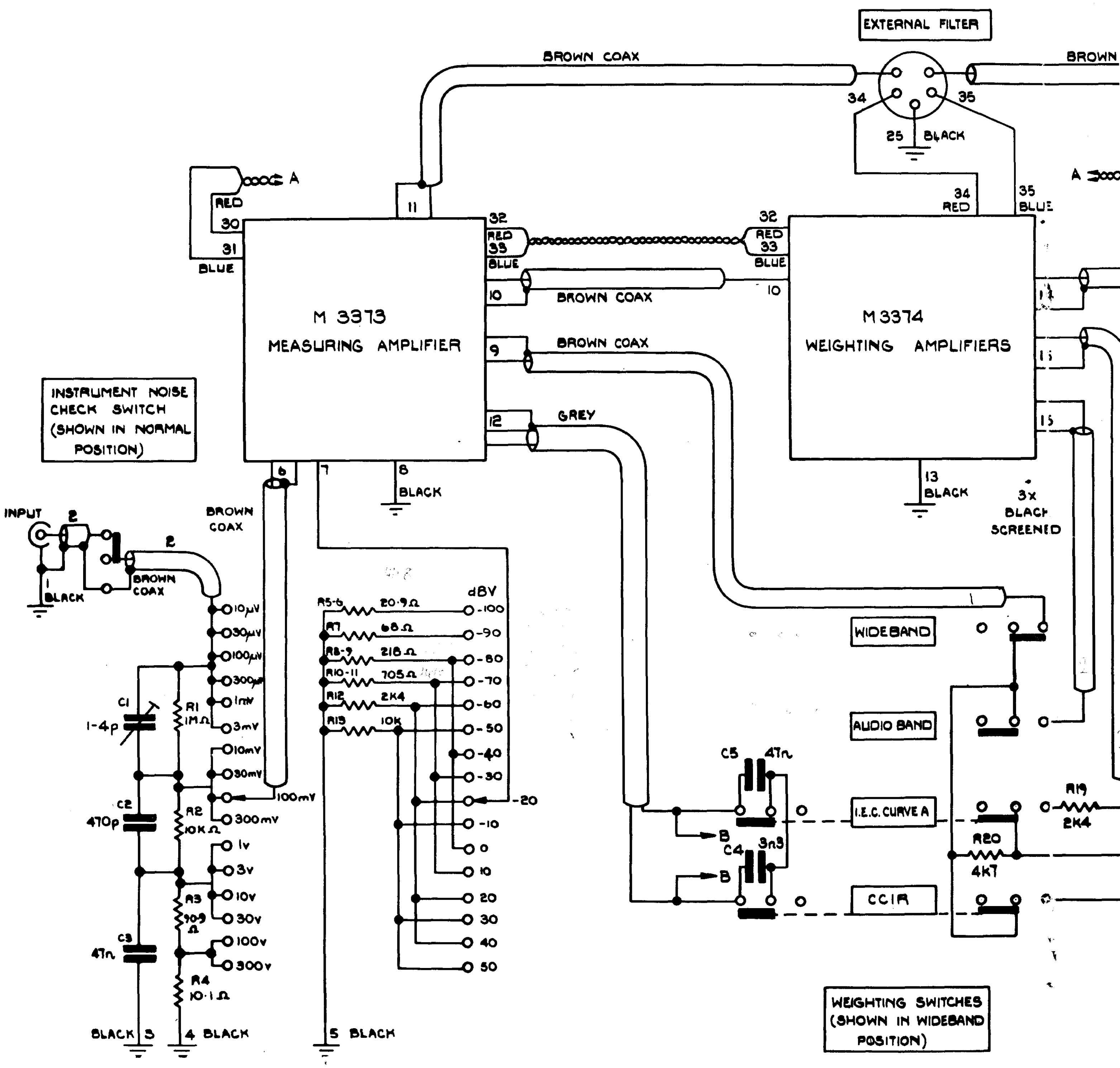
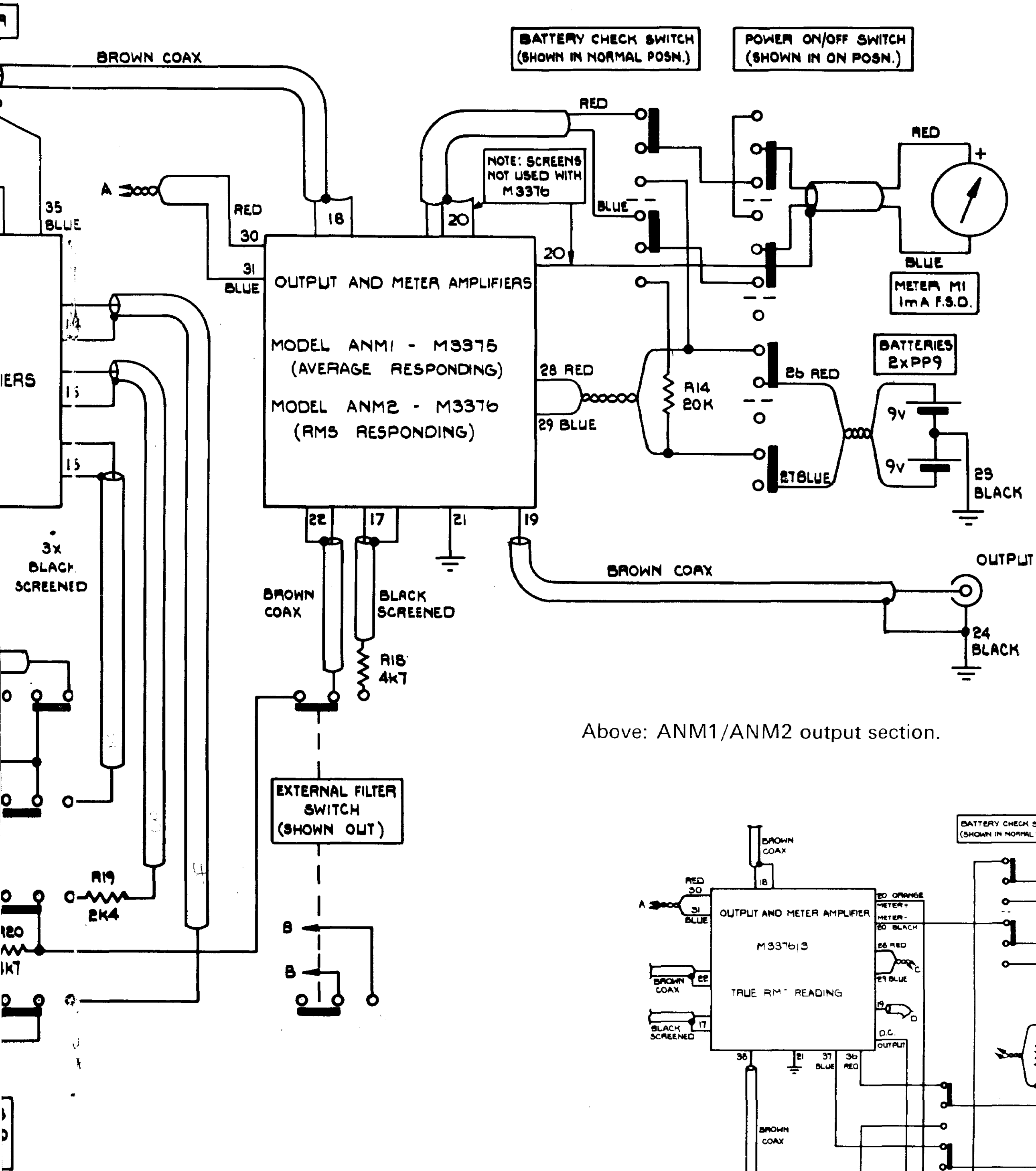
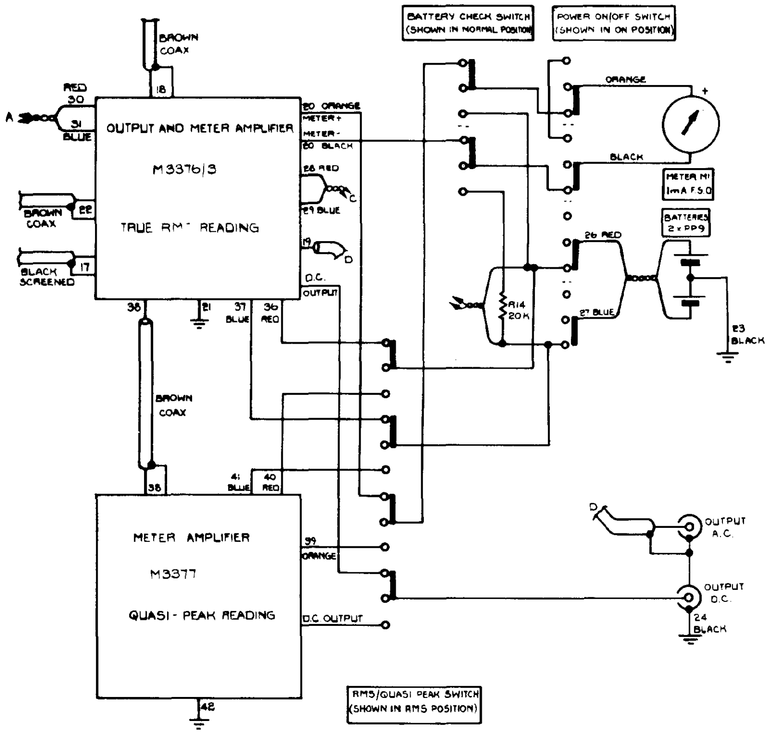


FIG. 6 SCHEMATIC DIAGRAM. Noisemeters only.



Above: ANM1/ANM2 output section.



ANM3 ONLY output section.

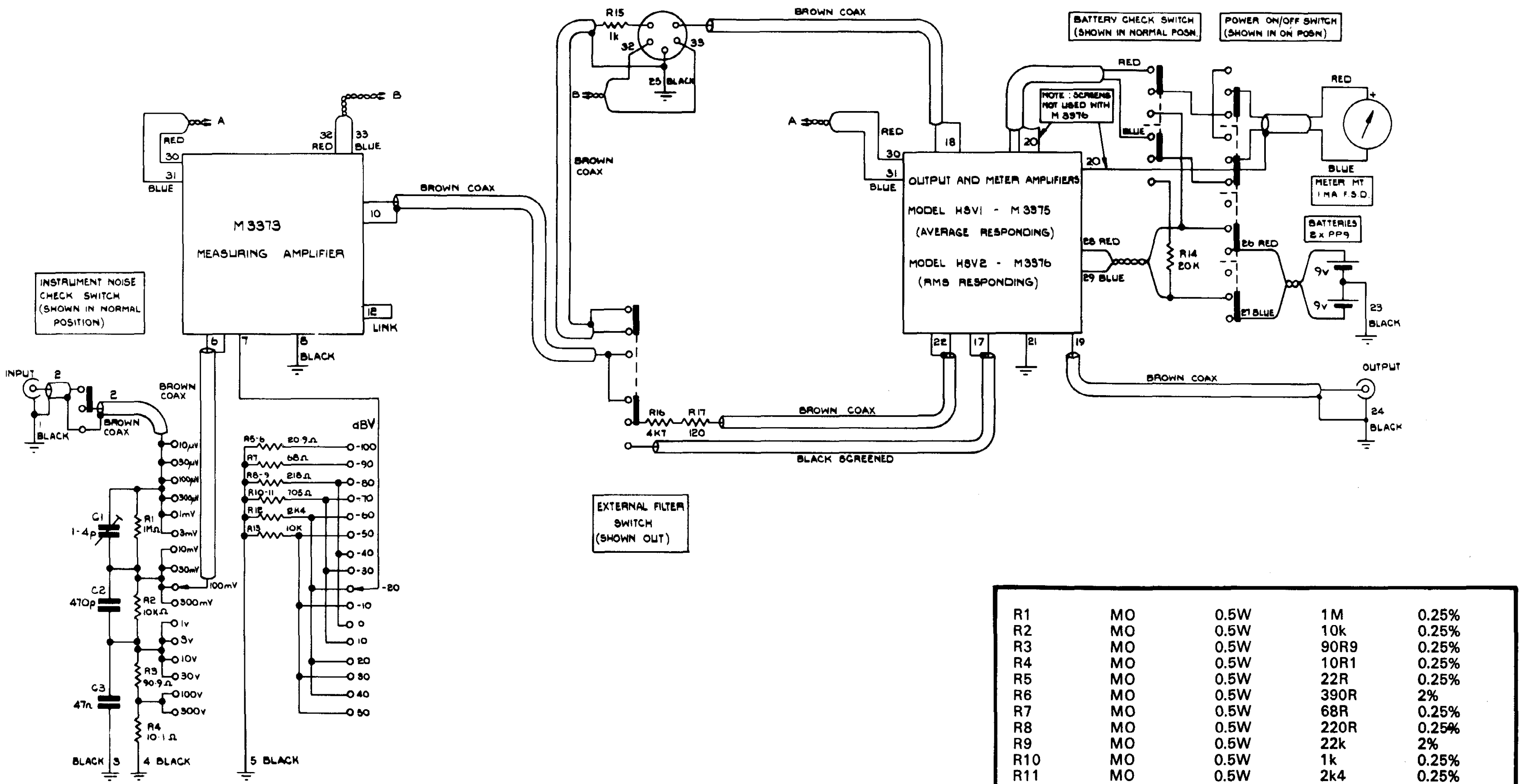
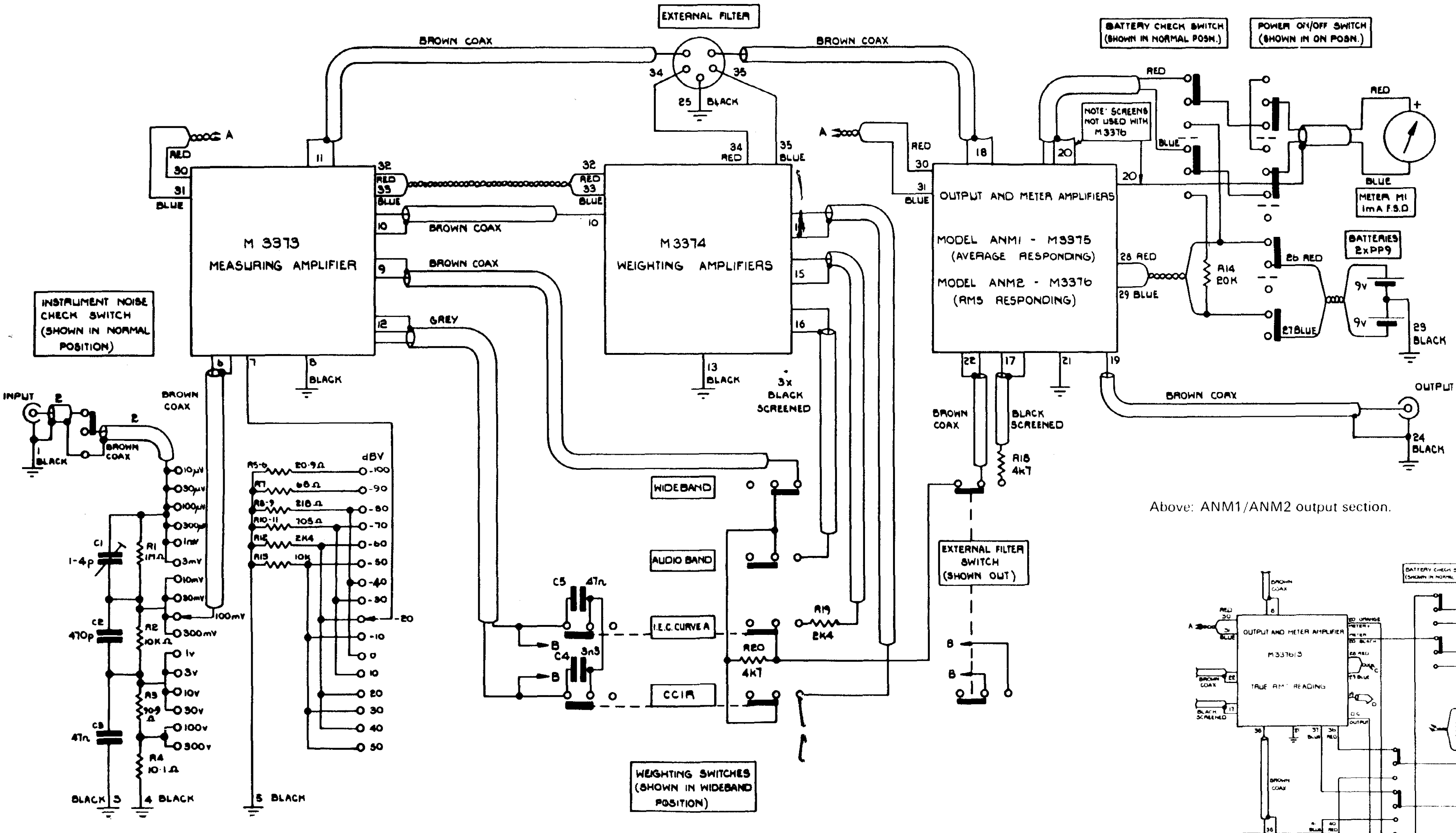


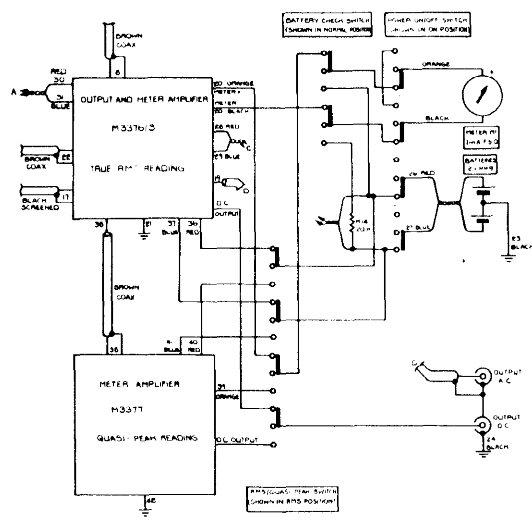
FIG. 7 SCHEMATIC DIAGRAM. Voltmeters only.

R1	MO	0.5W	1M	0.25%	
R2	MO	0.5W	10k	0.25%	
R3	MO	0.5W	90R9	0.25%	
R4	MO	0.5W	10R1	0.25%	
R5	MO	0.5W	22R	0.25%	
R6	MO	0.5W	390R	2%	
R7	MO	0.5W	68R	0.25%	
R8	MO	0.5W	220R	0.25%	
R9	MO	0.5W	22k	2%	
R10	MO	0.5W	1k	0.25%	
R11	MO	0.5W	2k4	0.25%	
R12	MO	0.5W	2k4	0.25%	
R13	MO	0.5W	10k	0.25%	
R14	MO	0.5W	20k	2%	
R15	MO	0.5W	1k	2%	(V)
R16	MO	0.5W	4k7	2%	(V)
R17	MO	0.5W	120R	2%	(V)
R18	MO	0.5W	4k7	2%	(N)
R19	MO	0.5W	2k4	2%	(N)
R20	MO	0.5W	4k7	2%	(N)
C1	1-4pF	TRIMMER			
C2	PN	470pF	100V	1%	
C3	PR	0.047μF	100V	1%	
C4	PN	3300pF	100V	1%	(N)
C5	PR	0.047μF	100V	1%	(N)

(V) = Voltmeters only.
(N) = Noisemeters only.



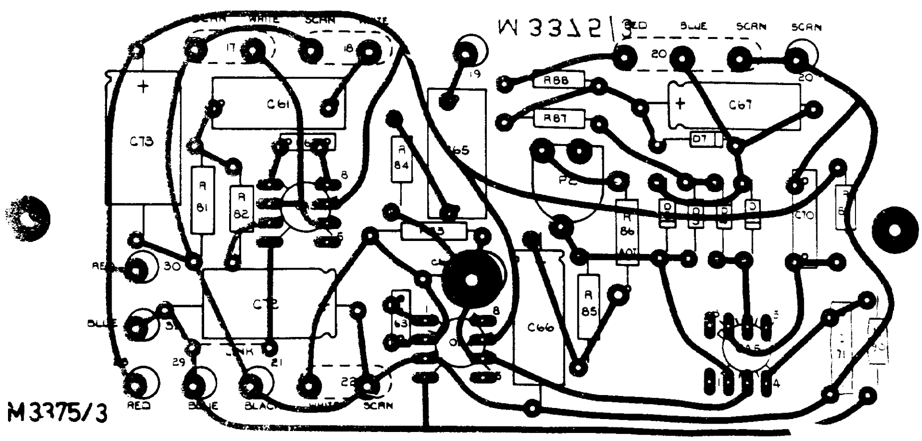
Above: ANM1/ANM2 output section.

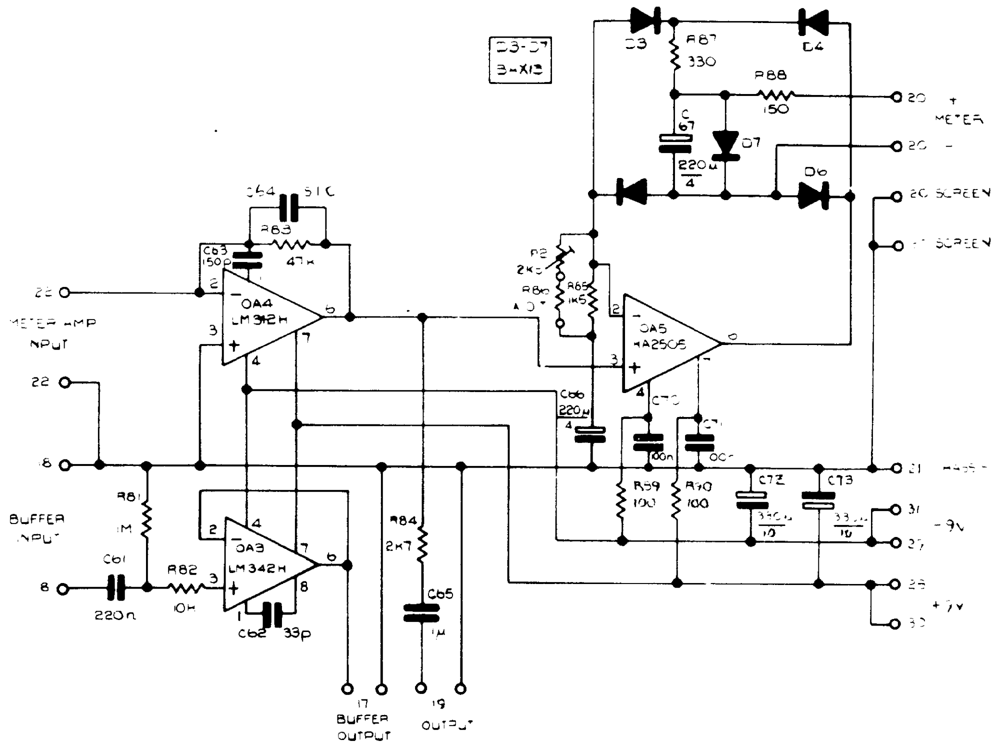


ANM3 ONLY output section.

FIG. 6 SCHEMATIC DIAGRAM. Noisemeters only.

FIG. 8 METER AMPLIFIER MODULE M3375. (Average sensing).





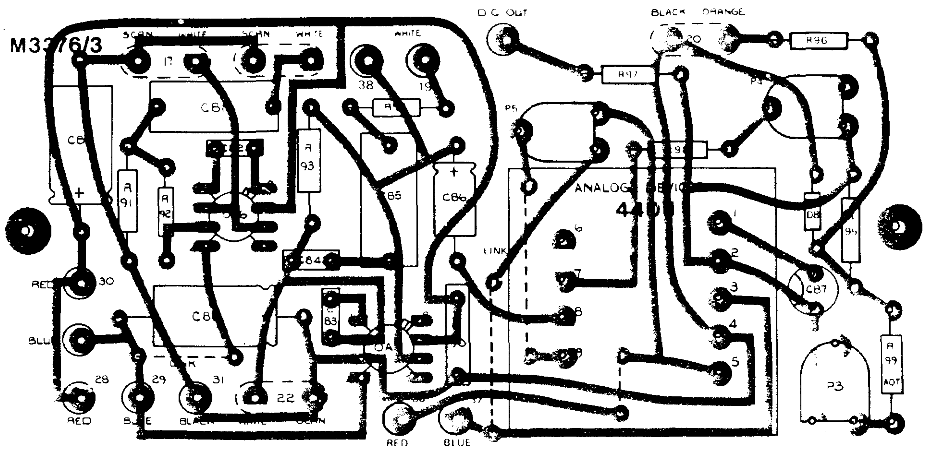
R81	MO	0.5W	1M	2%
R82	CF	0.25W	10k	5%
R83	MO	0.5W	47k	2%
R84	CF	0.25W	2k7	5%
R85	MO	0.5W	1k2	2%
R86	MO	0.5W	A.O.T.	2%
R87	CF	0.25W	330R	5%
R88	CF	0.25W	150R	5%
R89	CF	0.25W	100R	5%
R90	CF	0.25W	100R	5%

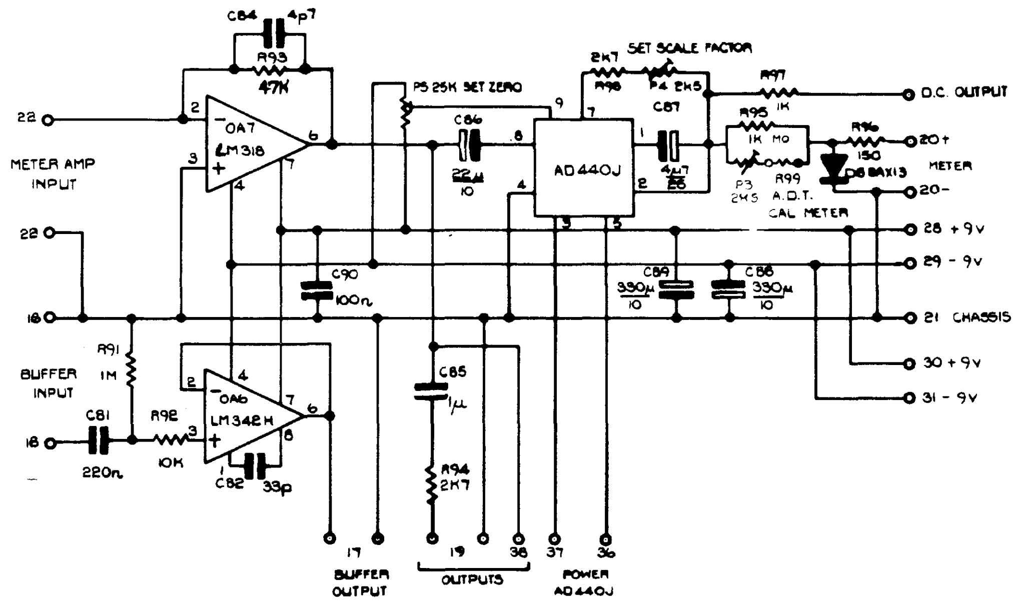
D3	BAX13
D4	BAX13
D5	BAX13
D6	BAX13
D7	BAX13

OA3	LM301
OA4	LM301
OA5	LM318

P2	HORIZONTAL SKELETON PRESET 2k5			
C61	PR	0.22µF	100V	10%
C62	CR	33pF	63V	
C63	CR	150pF	63V	
C64	CR	4.7pF	63V	
C65	PR	1µF	100V	10%
C66	E	220µF	4V	
C67	E	220µF	4V	
C68	NOT USED			
C69	NOT USED			
C70	PR	0.1µF	100V	10%
C71	PR	0.1µF	100V	10%
C72	E	330µF	10V	
C73	E	330µF	10V	

FIG. 9 METER AMPLIFIER MODULE M3376. (True r.m.s. sensing).





R91	MO	0.5W	1M	2%
R92	CF	0.25W	10k	5%
R93	MO	0.5W	47k	2%
R94	CF	0.25W	2k7	5%
R95	MO	0.5W	1k	2%
R96	CF	0.25W	150R	5%
R97	CF	0.25W	1k	5%
R98	MO	0.5W	2k7	2%
R99	MO	0.5W	A.O.T.	2%

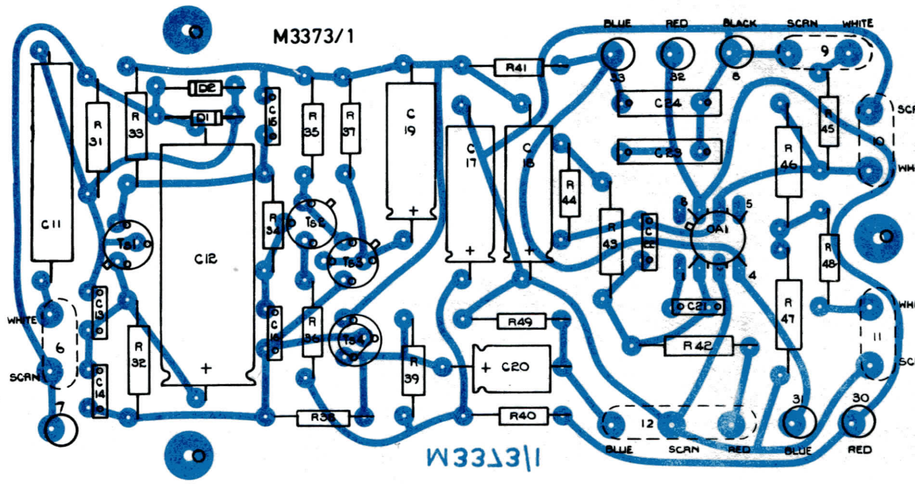
C81	PR	0.22µF	100V	10%
C82	CR	33pF	63V	
C83	NOT USED			
C84	CR	A.O.T.	63V	
C85	PR	1µF	100V	10%
C86	E	22µF	10V	
C87	E (TANT.)	4.7µF	25V	
C88	E	330µF	10V	
C89	E	330µF	10V	
C90	PR	0.1µF	100V	10%

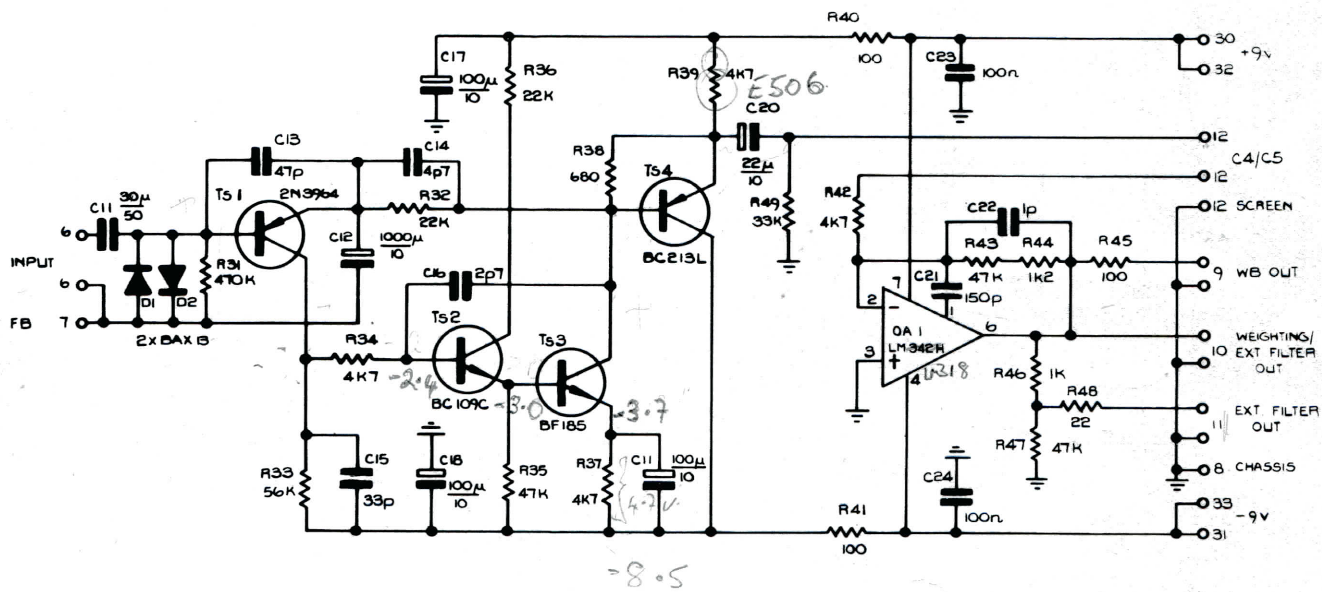
R.M.S. TO D.C. CONVERTER: ANALOG DEVICES 440J

P3	HORIZONTAL SKELETON PRESET	2k5
P4	HORIZONTAL SKELETON PRESET	2k5
P5	HORIZONTAL SKELETON PRESET	25k

OA6	LM301	D8	BAX13
OA7	LM318		

FIG. 4 MEASURING AMPLIFIER MODULE M3373.

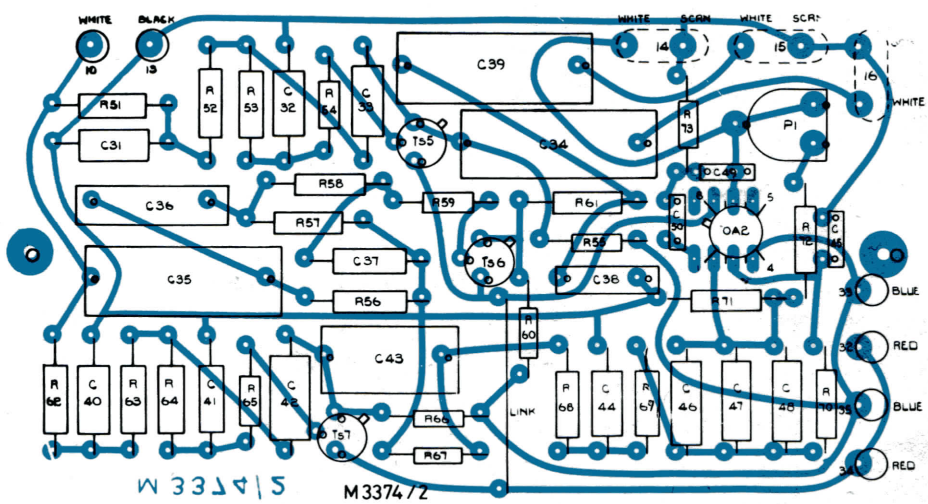


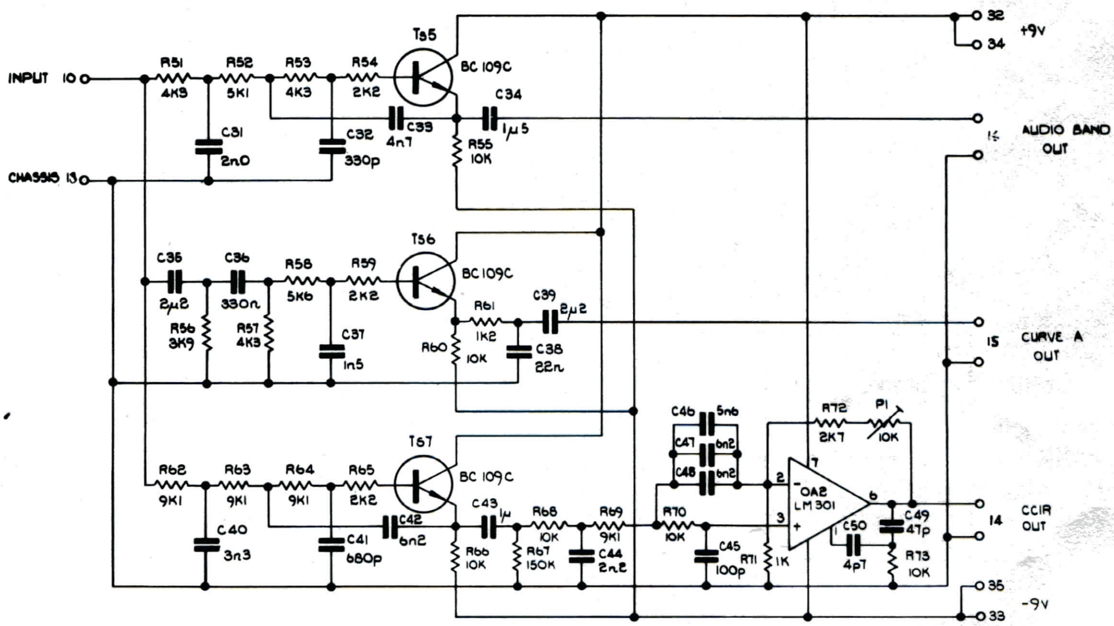


R31	MO	0.5W	470k	2%
R32	MO	0.5W	22k	2%
R33	MO	0.5W	56k	2%
R34	CF	0.25W	4k7	5%
R35	CF	0.25W	47k	5%
R36	CF	0.25W	22k	5%
R37	CF	0.25W	4k7	5%
R38	CF	0.25W	680R	5%
R39	See Text 6.1			
R40	CF	0.25W	100R	5%
R41	CF	0.25W	100R	5%
R42	MO	0.5W	4k7	2%
R43	MO	0.5W	47k	2%
R44	CF	0.25W	1k2	5%
R45	CF	0.25W	100R	5%
R46	MO	0.5W	1k	2%
R47	MO	0.5W	47k	2%
R48	CF	0.25W	22R	5%
R49	CF	0.25W	33k	5%

C11	E (REV.)	30μF	50V
C12	E	1000μF	10V
C13	CR	47pF	63V
C14	CR	4.7pF	63V
C15	CR	33pF	63V
C16	CR	2.7pF	63V
C17	E	100μF	10V
C18	E	100μF	10V
C19	E	100μF	10V
C20	E	22μF	10V
C21	CR	150pF	63V
C22	CR	A.O.T.	63V
C23	PR	0.1μF	100V
C24	PR	0.1μF	100V
TS1	2N3964		
TS2	BC109C		
TS3	BF185		
TS4	BC213L		
D1	BAX13		
D2	BAX13		
OA1	LM318		

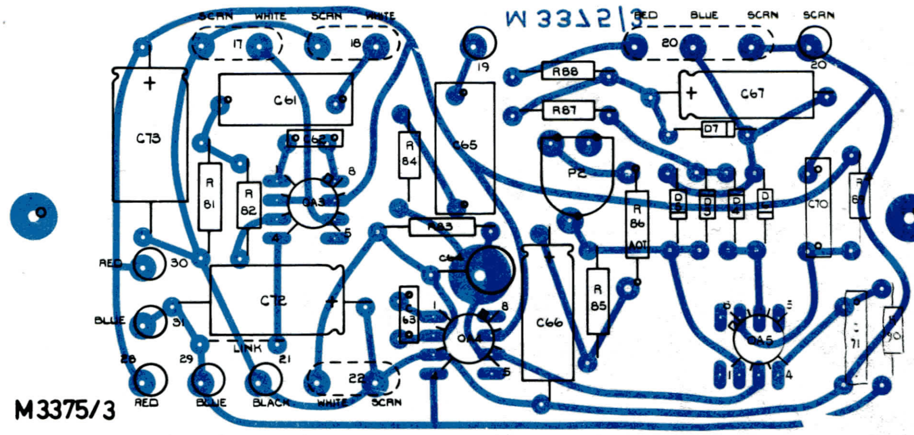
FIG. 5 WEIGHTING AMPLIFIER MODULE M3374. Noisemeters only.

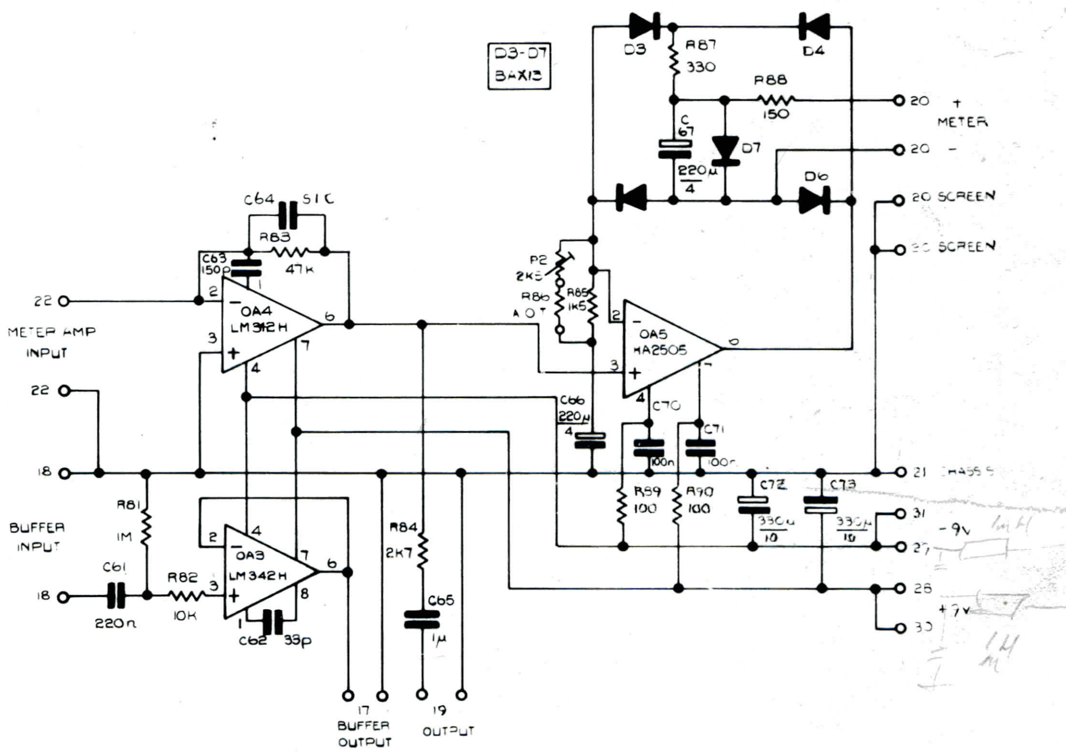




R51	MO	0.5W	4k3	2%	C31	PN	2000pF	100V	1%
R52	MO	0.5W	5k1	2%	C32	PN	330pF	100V	1%
R53	MO	0.5W	4k3	2%	C33	PN	4700pF	100V	1%
R54	CF	0.25W	2k2	5%	C34	PR	1.5µF	100V	10%
R55	CF	0.25W	10k	5%	C35	PR	2.2µF	100V	10%
R56	MO	0.5W	3k9	2%	C36	PR	0.33µF	100V	10%
R57	MO	0.5W	4k3	2%	C37	PN	1500pF	100V	1%
R58	MO	0.5W	5k6	2%	C38	PR	0.022µF	100V	10%
R59	CF	0.25W	2k2	5%	C39	PR	2.2µF	100V	10%
R60	CF	0.25W	10k	5%	C40	PN	3300pF	100V	1%
R61	MO	0.5W	1k2	2%	C41	PN	680pF	100V	1%
R62	MO	0.5W	9k1	2%	C42	PN	6200pF	100V	1%
R63	MO	0.5W	9k1	2%	C43	PR	1µF	100V	10%
R64	MO	0.5W	9k1	2%	C44	PN	2200pF	100V	1%
R65	CF	0.25W	2k2	5%	C45	CR	100pF	63V	
R66	CF	0.25W	10k	5%	C46	PN	5600pF	100V	1%
R67	CF	0.25W	150k	5%	C47	PN	6200pF	100V	1%
R68	MO	0.5W	10k	2%	C48	PN	6200pF	100V	1%
R69	MO	0.5W	9k1	2%	C49	CR	47pF	63V	
R70	MO	0.5W	10k	2%	C50	CR	4.7pF	63V	
R71	MO	0.5W	1k	2%					
R72	MO	0.5W	2k7	2%					
R73	CF	0.25W	10k	5%	TS5	ZTX109C			
					TS6	ZTX109C		OA2	LM301
P1	HORIZONTAL SKELETON PRESET			10k	TS7	ZTX109C			

FIG. 8 METER AMPLIFIER MODULE M3375. (Average sensing).



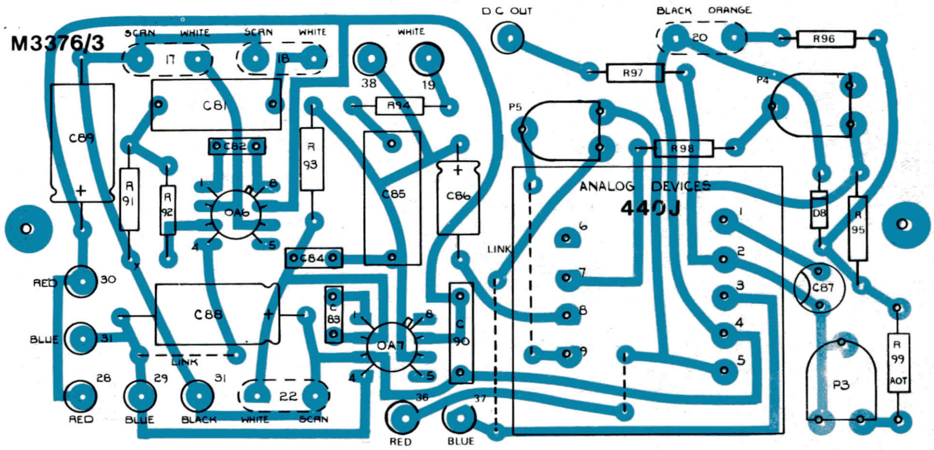


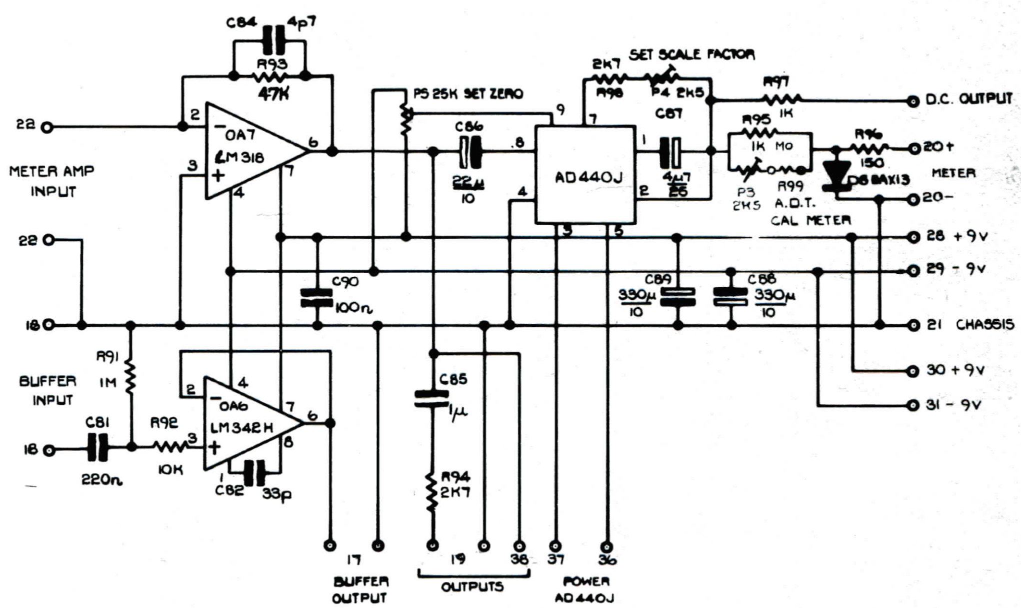
R81	MO	0.5W	1M	2%
R82	CF	0.25W	10k	5%
R83	MO	0.5W	47k	2%
R84	CF	0.25W	2k7	5%
R85	MO	0.5W	1k2	2%
R86	MO	0.5W	A.O.T.	2%
R87	CF	0.25W	330R	5%
R88	CF	0.25W	150R	5%
R89	CF	0.25W	100R	5%
R90	CF	0.25W	100R	5%

D3	BAX13	OA3	LM301
D4	BAX13	OA4	LM301
D5	BAX13	OA5	LM318
D6	BAX13		
D7	BAX13		

P2	HORIZONTAL SKELETON PRESET 2k5			
C61	PR	0.22µF	100V	10%
C62	CR	33pF	63V	
C63	CR	150pF	63V	
C64	CR	4.7pF	63V	
C65	PR	1µF	100V	10%
C66	E	220µF	4V	
C67	E	220µF	4V	
C68	NOT USED			
C69	NOT USED			
C70	PR	0.1µF	100V	10%
C71	PR	0.1µF	100V	10%
C72	E	330µF	10V	
C73	E	330µF	10V	

FIG. 9 METER AMPLIFIER MODULE M3376. (True r.m.s. sensing).





R91	MO	0.5W	1M	2%
R92	CF	0.25W	10k	5%
R93	MO	0.5W	47k	2%
R94	CF	0.25W	2k7	5%
R95	MO	0.5W	1k	2%
R96	CF	0.25W	150R	5%
R97	CF	0.25W	1k	5%
R98	MO	0.5W	2k7	2%
R99	MO	0.5W	A.O.T.	2%
P3	HORIZONTAL SKELETON PRESET			2k5
P4	HORIZONTAL SKELETON PRESET			2k5
P5	HORIZONTAL SKELETON PRESET			25k

C81	PR	0.22µF	100V	10%
C82	CR	33pF	63V	
C83	NOT USED			
C84	CR	A.O.T.	63V	
C85	PR	1µF	100V	10%
C86	E	22µF	10V	
C87	E (TANT.)	4.7µF	25V	
C88	E	330µF	10V	
C89	E	330µF	10V	
C90	PR	0.1µF	100V.	10%

R.M.S. TO D.C. CONVERTER: ANALOG DEVICES 440J

OA6	LM301	D8	BAX13
OA7	LM318		

earth or several pieces of equipment are connected in such a way that cable screens form a complete loop, causing circulating currents. The second condition occurs when the voltmeter is connected such that it provides the connection of the apparatus under test to mains earth.

3.2 Measurement

The average sensing (HSV1 and ANM1) and peak sensing (ANM3) instruments are calibrated to read the r.m.s. value with a sine wave input. Therefore, on all other waveforms, including random noise, there will be a difference between the observed reading and the true r.m.s. value.

It may be necessary when operating at low levels, to subtract the noise contribution of the measuring system from the total reading, in order to determine the value of the signal being measured. In most cases this contribution will be uncorrelated with the measured signal in which case they combine according to a square law.

Total reading $=\sqrt{(\text{Signal}^2+\text{Noise}^2)}$

4. MAINTENANCE AND CALIBRATION

4.1 Maintenance

The schematic diagrams figs 6 and 7 show the wiring of the instruments external to the printed circuit board modules.

It is not intended that p.c.b. modules in the Voltmeters and Noisemeters be repaired by component replacement. They should be replaced by factory tested modules should a fault occur. Physical layout diagrams of the instrument, Fig. 2 provide identification of modules and other components assemblies. Printed circuit board modules are fitted with 'Amp' type connectors to facilitate easy replacement.

For completeness, and for emergency repair, printed circuit board module layout diagrams are included (figs 4-5 and 8-10) which show the copper circuitry in relation to the components. The module terminations are numbered and colour coded to ensure correct lead connection after board replacement.

Should you require advice or the supply of any component, module or sub-assembly please write to the Service Department, Radford Laboratory Instruments Limited, Bristol

4.2 Calibration

It may be necessary to re-calibrate the instrument either to comply with a laboratory maintenance schedule or in the event of error following mechanical shock. The range to range accuracy of the instrument is governed by high stability metal film resistors in the attenuator and measuring amplifier and is not adjustable. The overall accuracy of the instrument is set by adjustment to the meter amplifier board (either M3375, M3376 or M3377) as detailed below.

4.2.1 For average and Peak Sensing Instruments

(M3375 and M3377 meter amplifiers)

(i) With instrument switched off, adjust mechanical zero of meter.

(ii) Switch instrument to 'Wideband' and to the 0dBv range and inject 1kHz sine wave at 1.00V r.m.s.

(iii) Set P2 (P6 on M3377) midway. Select a value of metal oxide resistor for R86 (R111 on M3377) (usually between 4k7 and 10k) which adjusts meter reading to within 1% of f.s.d.

(iv) Adjust P2 (P6 on M3377) to give precise f.s.d. (i.e. 0dBv)

4.2.2 For true r.m.s. Reading Instruments (M3376 meter amplifier)

(i) With instrument switched off, adjust mechanical zero of meter.

(ii) Connect a d.c. Digital Voltmeter to the D.C. output of the instrument, select 'External Weighting' and adjust P5 for zero on DVM.

(iii) Set instrument to 0dBv range and 'Wideband' weighting, inject 1kHz sine wave at 1.00 volts r.m.s. and set P4 for 1.00 volts D.C. on DVM.

(iv) Set P3 midway, select a value of metal oxide resistor for R99 (usually between 4k7 and 10k) which adjusts meter reading to within 1% of f.s.d.

(v) Adjust P3 to give precise f.s.d. (i.e. 0dBv)

If no Digital Voltmeter is available, do not adjust P4 and P5 but employ calibration procedure consisting of Para. 4.2.1 (i) and (ii) followed by Para. 4.2.2 (iv) and (v).

4.2.3 Adjustment of CCIR weighting network (M3374) 0dB frequency

An adjustment is provided on the weighting amplifier board of the noisemeters so that the 0dB frequency of the CCIR weighting curve may be set to the required standard (either 1kHz or 2kHz). Instruments with serial numbers up to and including 701391 left the factory with the 0dB frequency set to 2kHz. Instruments from serial number 701401 are set to 0dB at 1kHz (see below for method of adjustment of frequency at 0dB response).

(i) Inject the required frequency sine wave at 1 volt r.m.s. with the instrument on the 0dBv range to give precise f.s.d. on the wideband characteristic.

(ii) Switch to 'CCIR' weighting and adjust P1 for precise f.s.d.

5. GUARANTEE

Home

This instrument is guaranteed for a period of one year from the date of purchase. It covers the free replacement or repair of any defective component or part of the equipment during this period. It also covers the cost of labour in executing the repair or replacement if the instrument is returned to the factory service department, carriage paid, within the guarantee period.

Overseas

It is generally not practicable to return the instrument to the factory in England and instruments will normally be maintained in a serviceable condition by the replacement of sub-assemblies, modules or specific component parts.

In the case of instruments purchased through an agent in a country outside the U.K., the agent will act for the manufacturer in that country. Service enquiries should therefore be directed to the agent. If the instrument is purchased direct from the factory in countries where there is no Radford agent, enquiries should be directed to the Service Department in Bristol.

6. MODIFICATIONS

6.1 Modification to Measuring Amplifier M3373/1

This modification is essential in order to maintain the accuracy specification of the instruments with changes in battery voltage. The resistor R39 (4k7) is replaced by a current source type E506 (Siliconix). Measuring amplifier modules designated M3373/2 incorporate this modification.

6.2 Modification to Function Switch layout

This modification concerns factory production only.

The Function Switches 'External Weighting' and 'Noise Check' are interposed in order to improve the wiring layout and marginally improve the stability of the voltmeter on the −90dB and −100dB ranges when driven from a high source impedance.

Radford Laboratory Instruments Limited.

4 High Street, Nailsea, Bristol BS19 1BW. Tel. (02755) 6637

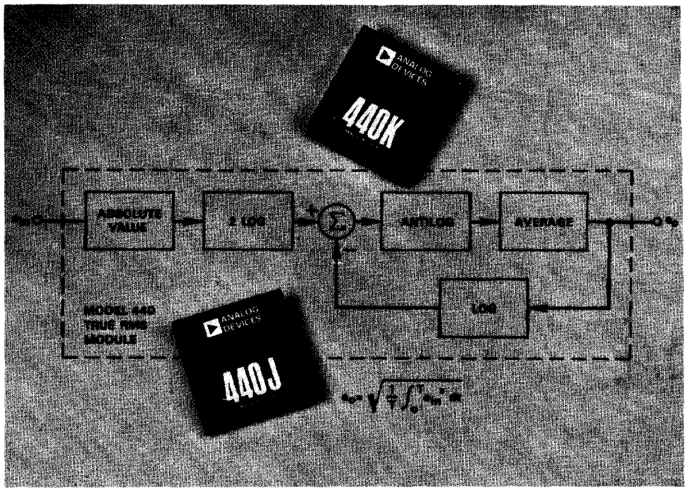
ANALOG DEVICES

Low Cost, General Purpose True RMS-to-DC Converter

MODEL 440

FEATURES
True RMS-to-DC Measurement
High Accuracy: 0.1% for C.F. ≤5
DC to 100kHz Response (1% Error)
All Hermetically Sealed Semiconductors
Low Cost:

APPLICATIONS
OEM RMS Instrumentation
Complex Waveform Measurements
SCR Controller & Power Line Measurements
Audio, Accoustic and Vibration Measurements
Mean Square Measurements
Random Thermal Noise Measurements



GENERAL DESCRIPTION

Model 440 is a compact economy RMS to DC converter module featuring performance usually found in higher priced units. In addition to measuring AC signals, model 440 can also measure directly the RMS value of a waveform containing both AC and DC. No external adjustments or components are required to achieve rated performance. For measurements below 100Hz, a single external capacitor may be added to achieve 0.1% accuracy without affecting the bandwidth for high frequency measurements.

Model 440 is available in two accuracy grades: model 440K features total error of ±5mV ±0.1%, while model 440J has total error of ±15mV ±0.2%. Optional external scale factor and offset voltage trimming will significantly reduce error for both models.

WHERE TO USE MODEL 440

OEM Instrument Designers will find the small size, low cost and high accuracy of model 440 makes it an excellent choice wherever RMS measurements must be made independent of waveform. This design offers significant accuracy improvements over the common rectifier-averaging type of meter. For example, the rectifier-averaging instrument has an error of 64% of reading on a 10% duty cycle pulse train, while the model 440 will provide less than 1% error by comparison. For industrial measurements, such as SCR motor controllers, as well as line voltage measurements, with high harmonic distortion, model 440 features high crest factor capability resulting in measurement errors less than ±1%.

The RMS value of any stationary zero-mean random signal is equal to the standard deviation (σ) of that signal. Accurate measurements of random signals, including acoustical noise, mechanical vibration and electrical noise are easily accomplished.

Model 440 may also be connected (see Figure 3) to measure the Mean Square of a signal ($e_o = \overline{e_{in}^2}/V_R$). The Mean Square of a random signal is equal to the variance (σ^2).

TOTAL ACCURACY

Total output error is specified as the sum of two components; a fixed term plus a percentage of peak output signal. Model 440K, for example, has a rated accuracy of ±5mV ±0.1%, which for a one volt RMS sinewave, results in a ±6mV maximum error (±5mV fixed error plus ±1mV reading error). The fixed error component is composed of output offset and input offset errors. The % of reading error is attributed to nonlinearity and scale factor errors. Scale factor error may be reduced by external adjustment of an optional 5kΩ potentiometer (see Figure 2). Offset voltage can also be trimmed to zero by external adjustment of an optional 20kΩ pot.

Accuracy is also dependent on the input signal frequency, amplitude and crest factor which are discussed in detail below.

HIGH FREQUENCY PERFORMANCE VERSUS SIGNAL LEVEL

Shown in Figure 4 is a plot of reading error versus frequency with input signal amplitude as a parameter. This error arises because of internal limitations in slew rate capability for large signal levels. At small signal levels, slew rate limiting is not predominant. Therefore, to achieve best accuracy in wideband applications with model 440, the designer should consider scaling down the input signal to optimize performance as shown in Figure 4.

(continued on page 3)

P.O. Box 280; Norwood, Massachusetts 02062 U.S.A.
Telex: 924491 Cables: ANALOG NORWOODMASS

SPECIFICATIONS (typical @ +25°C and V_S = ±15VDC, unless otherwise noted)

MODEL	440J	440K
TRANSFER EQUATION	$e_O = \sqrt{\text{avg } (e_{in})^2}$	*
ACCURACY		
Total Error[1]		
No External Adjustment	±10mV ±0.2%, Max	±5mV ±0.1%, Max
External Adjustment[2]	±2mV ±0.1%, Max	±2mV ±0.05%, Max
vs. Temperature (0 to +70°C)	±(0.2mV ±0.02%)/°C, Max	*
vs. Supply Voltage	±0.2mV/V	*
CREST FACTOR		
Rated Accuracy	5 Min	*
±1% Reading Error	10	*
FREQUENCY RESPONSE, Sinewave		
Rated Accuracy		
Input Range, 0.1 to 7V_{rms}	10kHz, Min	*
±1% Reading Error		
Input, 7V_{rms}	50kHz, Min	*
Input, 0.7V_{rms}	50kHz, Min	*
Bandwidth, -3dB		
Input Range, 0.7 to 7V_{rms}	500kHz	*
Internal Filter Time Constant	10ms	*
External Filter Time Constant[3]	50ms/µF	*
Total Averaging Time Constant	10ms + 50ms/µF	*
OUTPUT SPECIFICATIONS		
Rated Output[4]		
Voltage	+10.0V, Min	*
Current	+10.0mA, Min	*
Resistance	0.1Ω	*
Offset Voltage		
Internally Trimmed[5]	±5mV, Max	±2mV, Max
External Trim	Adjustable to Zero	*
INPUT SPECIFICATIONS		
Voltage		
Signal Range	±10V, Peak	*
Safe Input	±V_S, Max	*
dB Range, Referred to 1V	-40dB to 17dB	*
dBm Range, referred to 0.775V (1mW in 600Ω)	-38dBm to 19dBm	*
Impedance	8.3kΩ ±2%	*
Offset Voltage	±1mV, Max	*
vs. Temperature (0 to +70°C)	±10µV/°C	*
POWER SUPPLY[6]		
Voltage, Rated Performance	±15VDC	*
Voltage, Operating	±(6 to 18)VDC	*
Current, Quiescent	±10mA	*
TEMPERATURE RANGE		
Rated Performance	0 to +70°C	*
Operating	−25°C to +85°C	*
Storage	−55°C to +125°C	*
MECHANICAL		
Case Size	1.5" x 1.5" x 0.4"	*
Mating Socket	AC1016	*
Weight	40g	*

*Specifications same as Model 440J.

[1] Error is specified as the sum of two components: a fixed term plus a percentage of output signal. The fixed error component is composed of output offset error, and input offset error. The percentage of output signal (reading error) may be reduced by external adjustment of a scale factor potentiometer.

[2] See Figure 2 for connection of optional external scale factor adjustment pot.

[3] Connect optional filter capacitor between pin 1 and pin 2 (see Figure 2). Pin 1 is protected for shorts to ground and the positive supply voltage. Pin 1 is not protected for negative voltages greater than 1 volt.

[4] Protected for short circuit to ground and/or supply voltage.

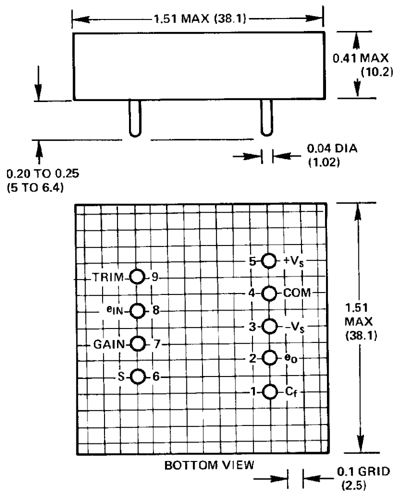
[5] Output offset voltage may be adjusted to zero. See Figure 2 and Figure 3 for connection diagram of optional 20kΩ pot. Adjustment range; ±20mV.

[6] Recommended power supply: Analog Devices' Model 915.

Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



MATING SOCKET AC1016

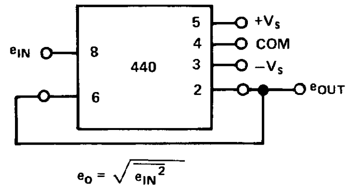
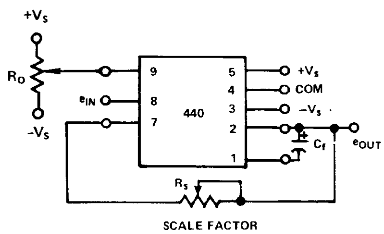
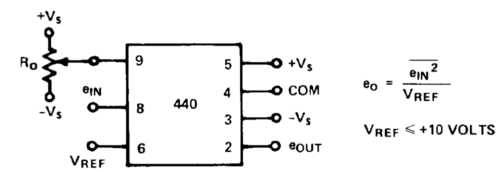


Figure 1. Wiring Connections for RMS Measurements (No External Trim)



R_S = 5kΩ, ANALOG DEVICES 79PR5k
R_O = 20kΩ, ANALOG DEVICES 79PR20k
Select C_f for increased averaging time constant.
(τ(ms) = 10 + 50 C_f (µF))

Figure 2. Optional External Adjustment for RMS Measurements



R_O = 20kΩ, ANALOG DEVICES 79PR20k

Figure 3. Wiring Connections for Mean Square Measurements with Adjustable Scale Factor (V_{REF})

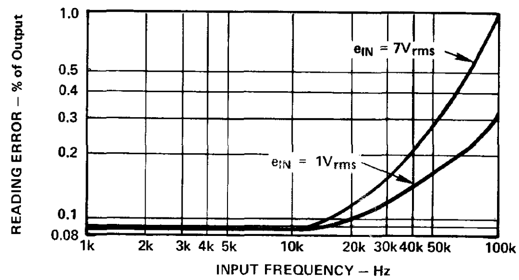


Figure 4. Error vs. Frequency, Sinewave Input

LOW FREQUENCY PERFORMANCE VERSUS FILTER TIME CONSTANT

Shown in Figure 5 is a plot of reading error versus frequency with the external filter capacitor (C_f) as a parameter. This capacitor is selected to increase the filter time constant to reduce output ripple for low frequency measurements. Accuracy at high frequencies is not affected by C_f.

In selecting the external filter capacitor, the lowest frequency component of the input signal should be determined. An averaging time constant (τ) of approximately 10 times the period of this frequency should then be selected. The averaging time constant of model 440 is determined from the following relation:

$$\tau\ (\text{ms}) = 10 + 50\ C_f\ (\mu\text{F})$$

Low leakage capacitors, such as tantalum electrolytic are recommended. Figure 5 shows curves for C_f values of 0, 1, 10 and 33μF and may be used to bracket the reading errors when other values are selected.

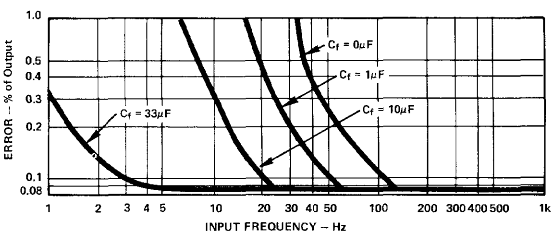


Figure 5. Error vs. Frequency, Sinewave Input

SETTLING TIME RESPONSE VERSUS FILTER TIME CONSTANT

Although there is no upper limit on how large a capacitor may be used to reduce ripple at low frequencies, there is a practical limitation due to increased settling time for step changes in RMS level occurring at the input. Figure 6 shows curves of settling time to 1% accuracy for increasing and decreasing one volt RMS input step changes. Increasing step changes (10mV to 1V_{rms}) settle to approximately three time constants (τ (ms) = 10 + 50C_f); decreasing step changes (1V_{rms} to 10mV) settle to approximately 5 time constants. The designer must consider optimizing settling time and low frequency error in selecting the external filter capacitor.

RMS MEASUREMENT ACCURACY AND CREST FACTOR

Crest factor is frequently understated in importance for RMS measurements, yet it is key to determining the accuracy of a true RMS measurement on a specific waveform. Crest factor is defined as the ratio of the peak signal amplitude to the RMS value (C.F. = V_p/V_{rms}). Figure 7 shows crest factor and RMS values for most frequently encountered waveforms. The examples shown illustrate that most common waveforms have relatively low crest factors (<2). Waveforms such as low duty cycle pulse trains have high crest factors (e.g. for a 1% duty cycle pulse train, crest factor is 10).

The peak signal input for model 440 is rated at ±10V. Crest factor, peak input voltage and RMS level are related by the crest factor definition; C.F. = V_p/V_{rms}. Therefore, for a particular waveform the max RMS input range may be determined from the signal crest factor. For example, for a sinewave, crest factor is 1.41. Therefore V_{rms} (max input) = 10V/1.41 = 7V_{rms}.

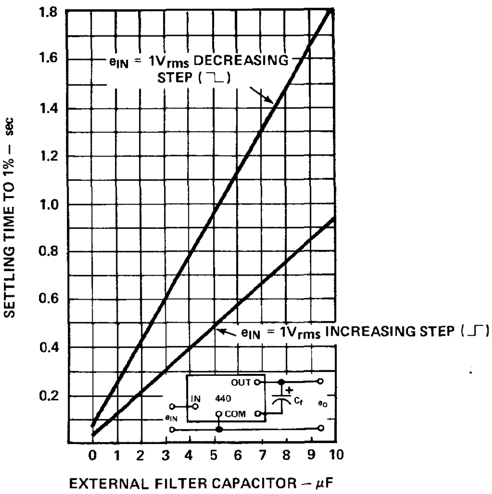


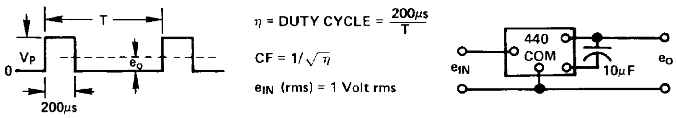
Figure 6. Settling Time vs. Filter Capacitor (C_f)

INPUT WAVEFORM	CREST FACTOR (= V_p/V_{rms})	RMS OUTPUT	RMS OUTPUT FOR V_p = 10 VOLTS
SINE WAVE	$\sqrt{2}$ (= 1.414)	$\frac{V_p}{\sqrt{2}}$	7V_{rms}
SYMMETRICAL SQUARE WAVE (OR DC)	1	V_p	10V_{rms}
TRIANGULAR WAVE	$\sqrt{3}$ (= 1.732)	$\frac{V_p}{\sqrt{3}}$	5.77V_{rms}
GAUSSIAN NOISE 2V_p CREST FACTOR 1 2 3 4 5 10^{-6} 10^{-3} 10^{0} PROBABILITY OF GREATER CREST FACTORS EXAMPLE: C.F. > 4 HAS A PROBABILITY OF < 0.01%		RMS	C.F. / V_{rms} 1 / 10 2 / 5 3 / 3.3 4 / 2.5 5 / 2
PULSE TRAIN T ηT	$\frac{1}{\sqrt{\eta}}$ η / C.F. 1 / 1 1/4 / 2 1/16 / 4 1/64 / 8 1/100 / 10	$V_p\sqrt{\eta}$ V_p 0.5 V_p 0.25 V_p 0.125 V_p 0.1 V_p	$10\sqrt{\eta}$ V_{rms} 10 V_{rms} 5 V_{rms} 2.5 V_{rms} 1.25 V_{rms} 1 V_{rms}
SINE-SQUARED	$\sqrt{8/3}$ (= 1.633)	$\frac{V_p}{1.63}$	6.13V_{rms}
SCR OUTPUT ϕ = 110°	1.68	$\frac{V_p}{1.68}$	5.95V_{rms}
SAWTOOTH PULSE 0 η 1	$\sqrt{\frac{3}{\eta}}$	$V_p\sqrt{\frac{\eta}{3}}$	$10\sqrt{\frac{\eta}{3}}$

Figure 7. Crest Factor and RMS Values for a Wide Class of Waveforms

ACCURACY AND SIGNAL CREST FACTOR

Shown in Figure 8 is a curve of reading error for model 440 with a one volt rms pulse train with variable duty cycle and peak amplitude. In this curve, pulse width (200μs) and RMS level (1 Volt) are held constant. The pulse train was selected because of its ability to generate a wide range of crest factors by varying the duty cycle (C.F. = $1/\sqrt{\eta}$). At a crest factor of 10, the peak input amplitude is 10 Volts (V_p = (C.F.) (V_{rms}). Therefore a one volt RMS level was selected to provide reading errors for crest factors from 1 to 10 (V_p from 1 to 10 Volts). Figure 8 may be used to estimate the reading error of the general class of waveform shown in Figure 7.



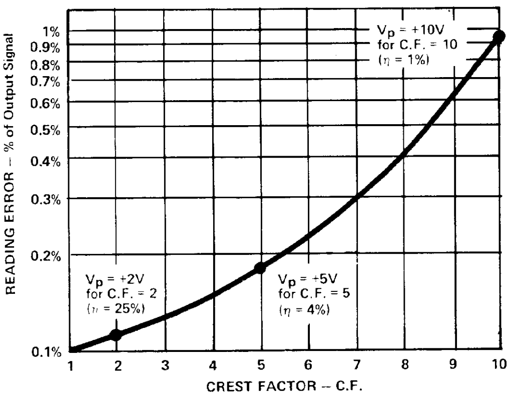


Figure 8. Error vs. Crest Factor

ACCURACY AND PULSE WIDTH

To relate error versus pulse width response, Figure 9 has been developed wherein crest factor and rms level are presented as parameters. Because of the extremely high frequency harmonic content in narrow pulse widths, the curves of Figure 9 present a worst case indication of error performance with frequency for the class of waveform shown in Figure 7. Model 440 may be used for pulse widths as small as 50μs with negligible additional error.

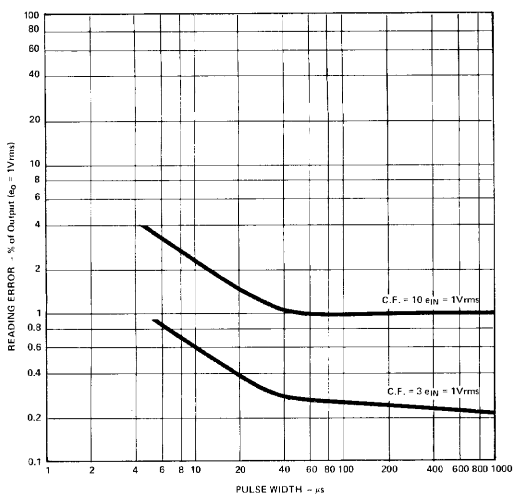


Figure 9. Error vs. Pulse Width and Crest Factor for Pulse Train

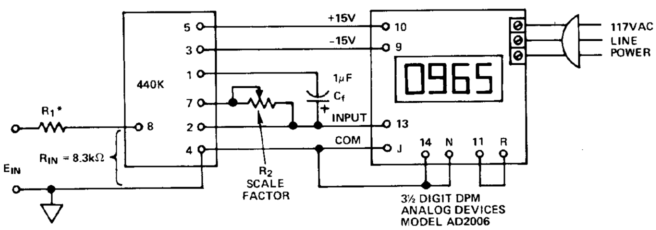
OPTIONAL EXTERNAL ADJUSTMENT PROCEDURE

Optional external trimming consists of two adjustments: output offset and scale factor. By the use of these two trims, overall accuracy may be improved significantly. To adjust output offset voltage, connect a 20k trim pot as shown in Figure 2 and short the input to common. Adjust for zero output voltage. To trim scale factor, connect a 5k trim pot as shown in Figure 2 and apply a positive DC input signal at the desired full scale RMS level (e.g., +1.000V). Adjust the scale factor pot until the output is equal to the input. Reverse the input polarity and measure the error in output level. Readjust the scale factor pot for lowest error for both polarity inputs.

When model 440 is used to perform mean square measurements, the output offset voltage may be adjusted to zero by means of a 20kΩ potentiometer connected as shown in Figure 3. To trim the output to zero, apply a +10V reference voltage to pin 6, and connect the input to signal common. Adjust the offset potentiometer for zero output.

TRUE RMS DIGITAL PANEL METER APPLICATION

Model 440 may be used to provide an economical, true RMS measurement capability for modular digital panel meters (DPM). Figure 10 illustrates an application of model 440 with a popular 3½ digit line powered DPM (Analog Devices' model AD2006). The low power requirements of model 440 allow the use of the DPM's external power outputs (±15V @ 10mA), eliminating the need for a separate power supply for model 440. The input resistor (R_1) provides the capability to easily set the nominal full scale input voltage to the DPM at 1 Volt for the peak input signal to be measured (E_{in}). For example, to measure 115VAC line voltage, R_1 would be selected for a 100:1 attenuation ratio (R_1 = 100 (R_{in}) = 830k. The external filter capacitor is selected to achieve desired accuracy for the input frequency range; a 1μF would give rated accuracy for 50–60Hz line frequencies (see Figure 5). For best accuracy, the scale factor potentiometer (R_2) would be adjusted with a precision reference voltage input; a 100VDC signal may be used with the 830kΩ.



*Select R_1 as required to scale e_{IN} for 1V DPM full scale input.

Figure 10. True RMS DPM Application Using AD2006 DPM Internal Power to Operate Model 440K

C186b–10–3/75

PRINTED IN U.S.A.