Audio measurements are easy with this

AC Millivoltmeter

While most people own a multimeter for routine measurements, they are lost when it comes to making audio measurements, particularly low level signals. This design will fill that need very well and at low cost.

by IAN POGSON

To be able to make measurements on most audio equipment you need a meter capable of measuring signals as small as a few hundred microvolts up to 30 volts or more. And the bandwidth of the instrument must at least equal the audio range of up to 20kHz and preferably more. The input impedance of the meter should be the standard one megohm, with small shunt capacitance.

Residual noise of the meter circuit should also be as low as possible, to enable the very low voltages to be read accurately. And since the unit will be used in sensitive audio circuits which may be upset by a mains-powered unit, the meter is battery powered so that it may "float".

Needless to say, our new AC millivoltmeter meets all these criteria (otherwise, we would not have published the circuit or, for that matter, listed the criteria) as can be seen by referring to the specification panel.

The unit is housed in a moulded utility box with an aluminium panel. This provides a compact unit at an economical cost. To provide sufficient shielding from electrical interference, a metal plate is also necessary on the bottom inside of the box.

Few components are used in the circuit and these are readily available at low cost. Just two integrated circuits and five diodes comprise the list of semiconductor devices. The integrated circuits are CA3140 Fet-input operational amplifiers. We used two op amps to obtain the necessary high overall gain and wide frequency response.

Both op amps are connected as non-inverting amplifiers and are AC-coupled. The first amplifier has a voltage gain of about 30. The second op amp functions as a current driver with the meter movement placed in the negative feedback network. This has the effect of cancelling the non-linearity and voltage drop of the diode bridge network.

Even so, germanium diodes have been specified in preference to silicon types because their lower forward voltage drop reduces the output slewing requirement of the op amp. This translates to improved bandwidth.

A silicon diode is used to protect the meter against overload while a 1000µF capacitor provides filtering of the rectified signal to reduce needle "jitter" at very low frequencies.

There are two trimpots. The 10kΩ trimpot is an offset control which enables "zeroing" of the meter while the 1kΩ trimpot is provided for calibration.

Most of the passive components, 18 resistors in fact, are used in the input voltage divider which provides nine switched ranges. The inter-range ratios are as close as possible to 0.316 which means that switching up or down range changes the sensitivity by exactly 10dB. This is very handy for measuring signal ratios in audio equipment.

The total resistance of the voltage divider is one megohm, and to arrive at the 0.316 ratio mentioned previously, the resistor values are 75 and 23.5. These are obtained by paralleling the preferred values of 150Ω and 47Ω or multiples thereof.

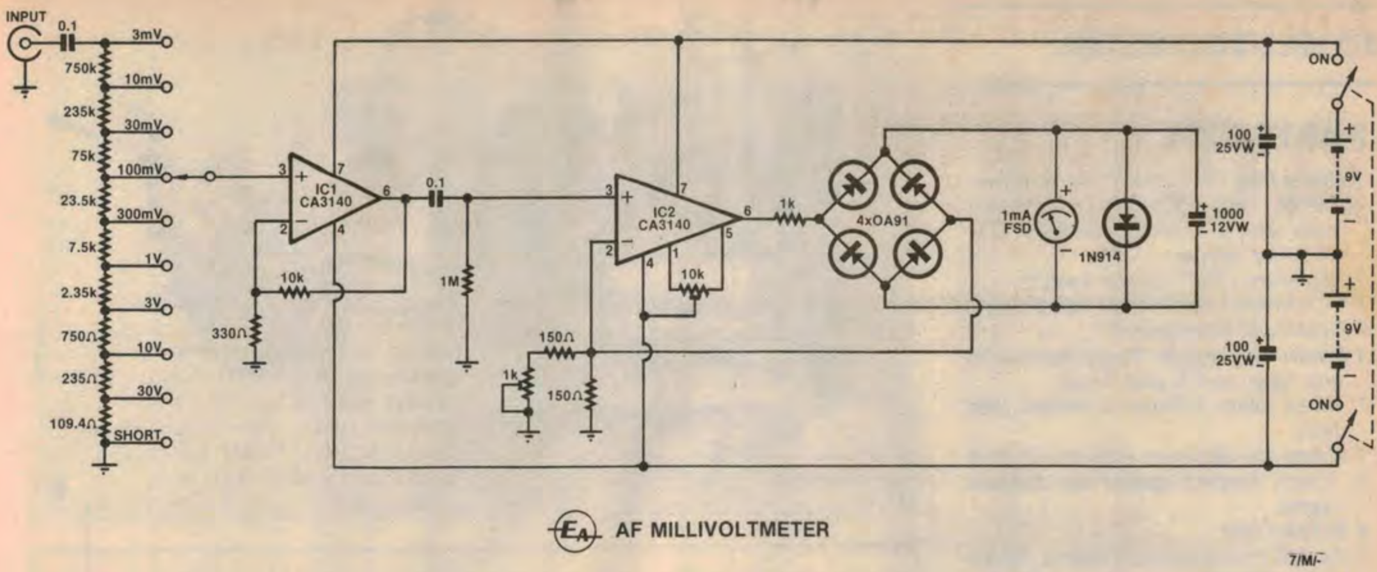
There are two exceptions to the idea of paralleling the values just mentioned and these are the two end positions. While it would be possible to arrive at 750kΩ by paralleling two 1.5MΩ resistors, it is not always easy to get low tolerance high stability types over 1MΩ. Hence we made up the 750kΩ by connecting a 680kΩ and a 68kΩ resistor in series. This actually adds up to 748kΩ, the nominal error being about 0.27%, which can be safely tolerated. The odd value of 109.4Ω at the bottom end of the divider is made up by connecting a 1.2k and 120Ω in parallel. This results in a value of 109.09Ω, giving an error of about 0.3% and which also may be ignored.

We have not followed the usual practice of compensating the voltage divider by shunting each section with an appropriate capacitor. It was found that without going to this extra cost and complexity, a top frequency of 20kHz or higher could be achieved and so we have taken the simpler course.

The unit is powered with two Eveready 216 9V batteries. With a current drain of only 5.5mA from each battery, they should last quite a while under normal service. To cope with the rising impedance of the batteries as they age, each one has been shunted with a 100µF electrolytic capacitor.

At the time of writing, all components for the Millivoltmeter are readily available. However, a few comments on

With nine ranges and three meter scales, including a decibel scale with zero reference of one milliwatt into 600Ω (774.6 millivolts RMS) our new AC Millivoltmeter is a handy instrument for audio measurements.



Two Fet-input op amps make up this useful instrument. The second op amp is a voltage-to-current converter to drive the meter.

the more important items may be helpful. The meter used on the prototype was supplied by University Graham Instruments Pty Ltd. It is type TD-86. University Graham are also making a special scale available for the meter for this project and supplies of the meter and scale should be available from most components outlets. If you have any problems in obtaining one of these meters, we suggest that you contact Radio Despatch Service, 869 George Street, Sydney 2000.

SPECIFICATION

A fully solid state AC millivoltmeter covering the audio frequency range and using two CA3140 Fet-input operational amplifiers. The unit is powered by two small 9V batteries, the current drain being about 5.5mA from each battery.

Nine ranges cover the FSD range 3mV to 30V RMS, with 10dB range ratios. The meter has three scales — a full length 0-10 scale, a 0-3 scale of slightly shorter length, and a decibel scale.

Frequently response of basic (3mV FSD) instrument is better than ±0.5dB from 5Hz to 30kHz. Minimum bandwidth on all ranges: ±0.5dB from 5Hz to 20kHz.

Input impedance: 1MΩ shunted by approximately 14pF on 3mV range, and approximately 7pF on all other ranges. Residual noise is equivalent to less than 200μV RMS input, with input open circuited but shielded.

The box which houses the unit is readily available from such places as Dick Smith Electronics, Rod Irving Electronics Radio Despatch Service and others. The printed circuit board and the Scotchal front panel overlay should be available from the usual outlets by the time this appears in print. If any difficulties are experienced obtaining these items, we suggest that you consult the list in the panel on the last page of the magazine, which gives names and addresses of suppliers of PCBs and Scotchcal panels.

The single-pole 10-position switch is available in a number of different makes and any one would be suitable. However, it is important that the switch be fitted with shorting-type contacts, otherwise the meter needle may swing violently when ranges are being switched.

CONSTRUCTION

Construction may begin by assembling the components on the PC board. When assembling any PC board it is usually best to start with the small components, such as resistors and diodes and following up with increasingly larger items. Care should be taken to make sure that all soldered joints are properly made and that all components are correctly polarised where applicable. Overheating of components and the use of soldering pastes should be avoided.

It will be seen that there are two large copper pads on the PC board. These should be carefully tinned all over so that they will be prevented from possible tarnishing in the future and to ensure that good contact is made when the PC board is screwed to the meter terminals.

Having finished the PC board and having satisfied that it is all correct, it may be put aside for the time being. The next step is to fix the input divider resistors to the range switch. A neat way of doing this is to mount the pairs of resistors radially to the switch. Care should be taken to make sure that the right resistors are fixed in each position, otherwise the final results will be found wanting!

> We estimate that the current cost of parts for this project is approximately
>
> **$38**
>
> This includes sales tax.

If you have elected to use a meter other than one similar to that used on the prototype, then you may be interested in making use of the meter scale which we have reproduced actual size, provided it will fit the meter of your choice.

To give the unit a professional finish, the Scotchcal overlay on the front panel will help in this regard. Fitting Scotchcal overlays to panels can be very tricky and calls for care and patience. In short, do not rush this task. Once the adhesive has grabbed any part of the panel, it is difficult to remove and so it is important that they be properly aligned before the two are brought together.

A helpful hint for fixing a Scotchcal overlay to a panel, is to align the overlay on the panel before removing the backing and pierce one or more suitable holes in the overlay, thereby matching similar holes on the panel. Then when the backing material is removed, screws or other guides may be put through the holes in the overlay and they can then be used as a means of aligning the two parts before they are pressed together.

The shield which was mentioned earlier is essential to the proper operation of the unit, particularly at the more sensitive ranges. We used a piece of scrap aluminium sheet and cut it to size and screwed to the base of the box. If you are unable to obtain easily a suitable piece of metal, then a piece of aluminium foil could be used. It would be a good idea to stick it to a piece of Formica or similar laminate, to give the aluminium some support and to keep it in place. It should be done in such a way that a solder lug makes good contact with it under a screw, so that it can be ef-

PARTS LIST

1 Utility box 197mm x 113m x 60mm
1 Meter 1mA FSD 86mm x 78mm with special scale. University TD-86-50 or similar
1 Miniature DPDT toggle switch
1 RCA socket single hole mounting
1 Scotchcal front panel
1 Rotary single-pole 10-position shorting type switch plus knob
1 shield plate 175mm x 90mm (see text)
1 clamp for batteries 60mm x 25mm
1 16mm tapped spacer for battery clamp
4 Rubber feet
1 Printed circuit board 95mm x 70mm code 80mv11
1 10kΩ miniature horizontal trimpot
1 1kΩ miniature horizontal trimpot
2 9V batteries type 216
2 clip leads to suit batteries
1 1N914 silicon small-signal diode
4 0A91 germanium small-signal diodes
2 CA3140 8-pin DIL op-amps
2 8-pin DIL sockets

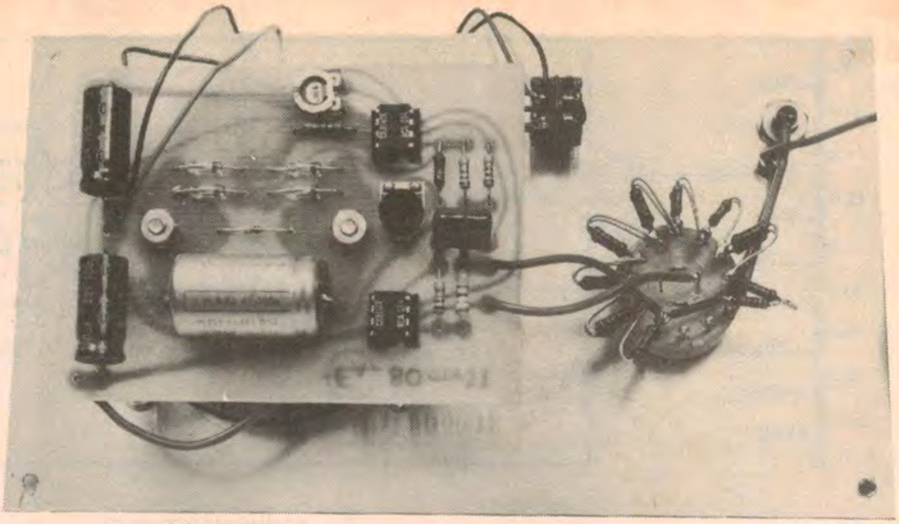
RESISTORS (¼W or ½W)
1 x 1MΩ, 1 x 10kΩ, 1 x 1kΩ, 1 x 330Ω, 2 x 150Ω

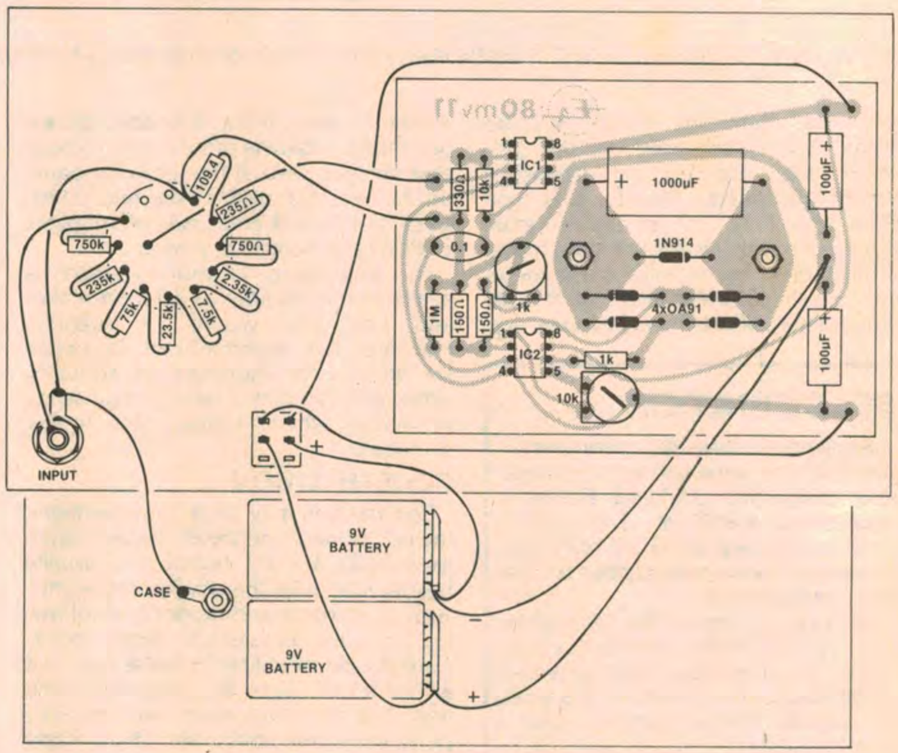
RESISTORS (2% high stability)
1 x 680kΩ, 2 x 470kΩ, 2 x 150kΩ, 1 x 68kΩ, 2 x 47kΩ, 2 x 15kΩ, 2 x 4.7kΩ, 2 x 1.5kΩ, 1 x 1.2kΩ, 2 x 470Ω, 1 x 120Ω

CAPACITORS
1 1000μF/12VW electrolytic
2 100μF/25VW electrolytics
2 0.1μF metallised polyester (greencap)

MISCELLANEOUS
Screws, nuts, hookup wire, solder, solder lug.

NOTE: – Ratings are those used on the prototype. Components with higher ratings may generally be used providing they are physically compatible.





fectively connected to the "earthy" side of the main circuit.

With the subassemblies ready, the next job is to do the final assembly. The metal shield is screwed to the bottom of the box, using at least two screws. A solder lug is fixed under the screw nearest to the input socket end of the front panel. The two batteries may now be clamped in place on the bottom of the box, at the same end as the solder lug. We used a brass spacer, 16mm long and threaded, between the two batteries, with the top clamp plate being screwed to the spacer.

The toggle switch, input socket, range switch and meter are now fixed to the front panel. When mounting the range switch, it is important that it be orientated so that when the knob is fitted, its pointer corresponds with the ranges on the panel.

The PC board is mounted directly on the back of the meter, using the meter screw terminals. But before doing this, all leads running from the PC board to points outside, should be fitted. These will include leads from the battery clips.

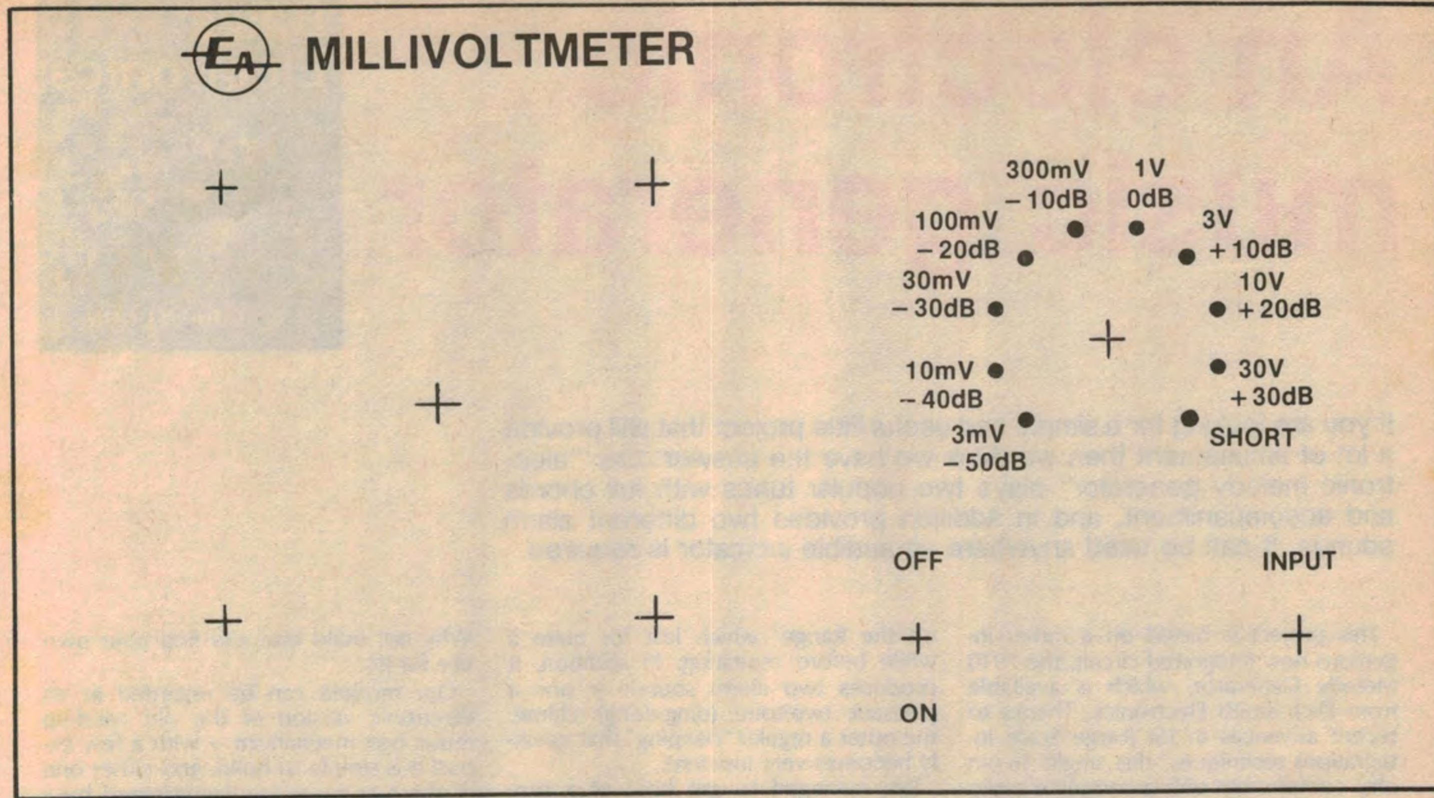
The remaining leads are terminated to the switches and input socket. The earthy lead from the board which terminates on the range switch is carried on to the corresponding lug on the input socket and then on to the lug on the bottom shield.

CALIBRATION

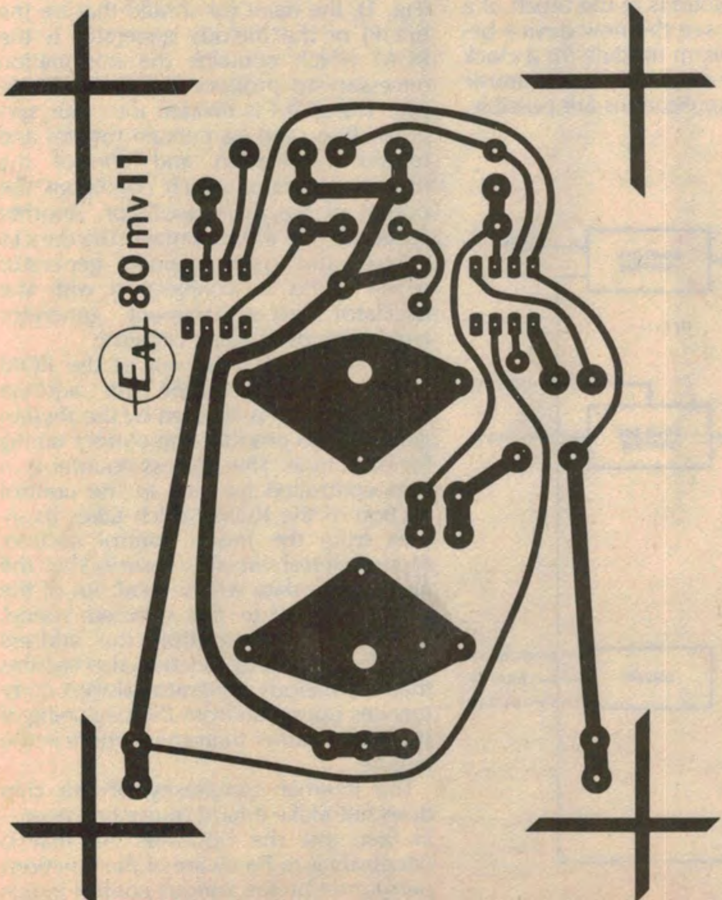
We are now ready to put the millivoltmeter into operation, after having made a final check to be sure that there are no errors or omissions. Set the two miniature trimpots to mid-travel and set the range switch to "short". Switch on and the meter needle will probably settle a little above zero on the scale. Carefully rotate the 10kΩ trimpot to obtain a zero scale reading on the meter.

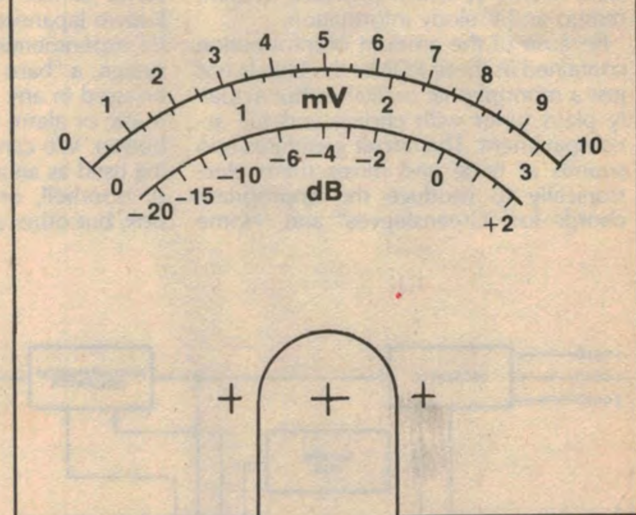
Calibration of the instrument should ideally be carried out by comparison with a reference instrument, using an audio generator set to approximately 1kHz at a level of 3.16mV, corresponding to FSD using the 3mV nominal sensitivity of the basic instrument. The 1k calibrating potentiometer is then adjusted to produce a reading of "10" on the 3mV range.

If a reference instrument of known accurate calibration is not available, a basic calibration will have to be performed using any available signal source having an amplitude known as accurately as possible. It would be preferable to have a level which gives as close as possible to a full scale reading, consistent with an



Shown on this page is the actual size artwork for the printed circuit board, front panel and meter scales. The front panel should be cropped to 191 × 107mm to provide a border.





appropriate setting of the range switch.

With the basic sensitivity set, all higher ranges will be determined by the voltage divider. As 2% high-stability resistors have been specified, the accuracy of each range should be within the tolerance of the resistors.

It should be noted that, in common with the majority of electronic meters, the instrument is fundamentally an average reading one which is calibrated in RMS values assuming a sinusoidal waveform. This fact should be taken into account particularly when performing initial calibration and it should also be borne in mind when subsequently using the instrument for measurements involving non-sinusoidal signals.