PRECISION DECIMAL STEP PRE-AMPLIFIER

by M. L. Michaelis M.A

THIS article sets out to discuss some of the important practical questions involved in the design of a universal pre-amplifier with transistors, capable of both audio and metric applications. A complete design is given as well, detailed drawings appearing on the blueprint included in this issue of PRACTICAL ELECTRONICS. This pre-amplifier was developed and built by the author primarily for use between the probe and Y-amplifier input of an oscilloscope and for use with a transistorised tape recorder for various laboratory experimental purposes. Obviously many further applications exist.

GENERAL CIRCUIT DETAILS

Fig. 1 on the blueprint shows the complete circuit diagram of the prototype. This comprises two separate circuit cards, each having a gain of exactly 10. A central switch S1 connects either one or both of these cards between the input and output terminals, giving gains of exactly 10 or 100 respectively, or, in its third position, it switches the unit off.

The left hand card VB1 contains three cascade transistors TR1–TR3 and a d.c. peak bypass input circuit to the base of TR1. The latter is an essential feature in a universal unit of this nature, to prevent destruction of the transistors due to d.c. charging surges of anything up to several hundred volts when connecting the input to the anode circuits of valve equipment.

It may seem strange to use three transistors for a gain of only 10, but this is necessary to achieve the required high constancy. When properly built and adjusted, this circuit shows no perceptible change of gain (as displayed on an oscilloscope or meter) over temperatures from the freezing point up to over 50°C (over 122°F), or for battery voltage variations between 6V and 11V.

The pre-amplifier design here described should be suitable for tropical temperatures when shielded from the direct rays of the sun, or for European summers, outdoors in full sunshine. Even considerable heating indoors, due to standing the unit on top of valve operated items of equipment of high power dissipation, should give no gain fluctuations or other troubles.

With the assurance that the gain really is rock steady throughout all working conditions likely to be met, it was convenient to make it exactly 10 per circuit card, wherewith the complete unit is a decimal-step pre-amplifier. The great advantage thereof is that, when used in conjunction with calibrated oscilloscopes, or with a.c. voltmeters, the existing scales can still be read-off and mentally multiplied or divided by powers of 10, i.e. a mere shift of the decimal point is required.

The right hand circuit card VB2 contains another identical cascade of three transistors TR4–TR6, giving a gain of 10 once again. The only difference compared to the first card is that the d.c. peak bypass circuit is here omitted, because the input signal is always applied to VB1. The right hand circuit card VB2 also contains the emitter follower output stage TR7.

The circuit of VB1 is always operative, in both the gain 10 and gain 100 settings of the complete pre-amplifier. In the gain 10 setting, TR7 is switched directly onto the output of TR3 in VB1 and TR4–TR6 idle with C4 shorting the base of TR4 for a.c. to prevent parasitic instability. C4 is connected up to the negative supply line (and not to chassis) for this purpose, to prevent application of d.c. voltages of incorrect polarity; either connection would be just as good for pure a.c. signal considerations.

In the gain 100 setting, the output of VB1 is connected through to the input of VB2, via C4, and the output at TR6 is connected through to TR7.

IMPEDANCE

If the pre-amplifier is to be used for metric purposes between the probe and the input socket of an oscilloscope or valve voltmeter, the input impedance must be equal to that of the instrument in question.

In the published design the input impedance at PL1 has been adjusted to exactly 135 kilohms to match the Y-amplifier input impedance of the author's oscilloscope. *Adjustment of the input impedance to other values will be fully discussed later. But, in brief, it should be explained that this will involve a change of values for R3, R4, R6, R8, R9, VR1, and VR2, also possibly the replacement of TR3 by an OC304.*

The output impedance at PL2 is very low, as given by the setting of VR2 or VR4 (the respective base feeds for TR7 in the gain 10 and gain 100 settings) divided by the current gain of TR7 (about 20); it is, in fact, about 500 ohms. The purpose of this low output impedance is to permit arbitrary lengths of uncompensated co-axial cable between the output and the oscilloscope Y-amplifier input without loss of bandwidth due to cable stray capacity.

TABLE 1: GENERAL & EXPERIMENTAL USES OF THE DECIMAL STEP PRE-AMPLIFIER

AUDIO INPUT FROM	SET S1 FOR GAIN OF	AMPLIFIED OUTPUT TO
crystal microphone or moving coil microphone with transformer	100	gramophone socket (pick-up) of domestic radio or simple amplifier
moving coil loudspeaker as microphone, without transformer	100	ditto
moving coil loudspeaker as microphone, with reversed output transformer (step-up) as matching	10	ditto
magnetic pick-ups	10 or 100, according to type	ditto
any microphone, close to decimal step pre-amplifier	10 or 100, according to length of cable to main amplifier	microphone input of *distant* public address amplifier (field-work over large areas)
crystal set or simple diode receiver	100	4,000 ohm headphones
any audio signal arising during experiments (many pulsed signals can also be handled—e.g. from photocells, Geiger counters, etc.)	10 or 100, as required	wherever required, unamplified signal having been insufficient

As far as audio uses are concerned, the low output impedance gives satisfactory performance on 4,000 ohm headphones, or even on ones of somewhat lower impedance, and long runs of screened cable are permissible from the output to a remote main amplifier without loss of treble when using the unit as a microphone head pre-amplifier.

PERFORMANCE

The bandwidth of the pre-amplifier as described in this article extends from 2c/s at the low frequency end on either gain setting to about 100kc/s at gain 100 or about 150kc/s at gain 10 at the high frequency end. These figures refer to the so-called 3dB-down points, i.e. the gain has dropped to one-half of that at mid-band frequencies at these limits. The response is substantially flat over the entire "hi fi" audio frequency range from 20c/s to 20kc/s and some way beyond either end.

Harmonic distortion is extremely low up to drives giving an output of 1 volt r.m.s.; it is not visible as deformation of a sinewave on an oscilloscope up to this signal level, a fairly sensitive visual test. Phase-shift is negligible, so that pulse and transient responses are excellent.

The unit is thus equally satisfactory for both high fidelity audio work and for waveform display on an oscilloscope.

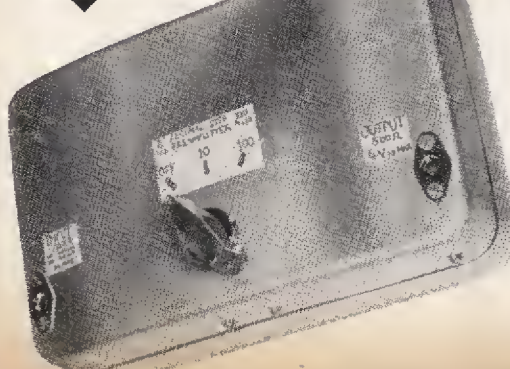
APPLICATIONS

Fig. 8 shows the manner in which the pre-amplifier may be connected to increase the Y-deflection sensitivity of an oscilloscope. The input impedance of the pre-amplifier must of course be adjusted to match the oscilloscope.

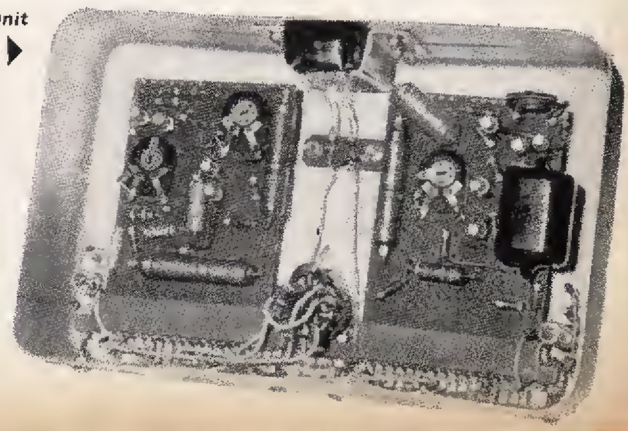
Fig. 9 sketches the arrangement to be adopted when using the pre-amplifier to increase the sensitivity of any a.c. valve voltmeter. The impedance matching requirements are here the same as for oscilloscopes if one desires to use the existing probe of the valve voltmeter at the input of the pre-amplifier while maintaining exact decimal step sensitivity increases.

If a simple diode peak rectifier circuit is interposed between the pre-amplifier output and the meter input, d.c. valve voltmeters or high resistance multimeters

Complete unit
External view



Complete unit
Internal view



PRECISION DECIMAL STEP PRE-AMPLIFIER

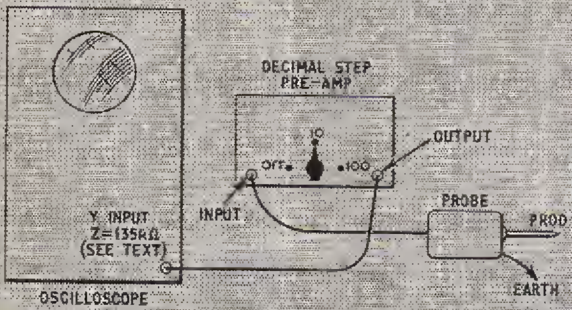


FIGURE 8

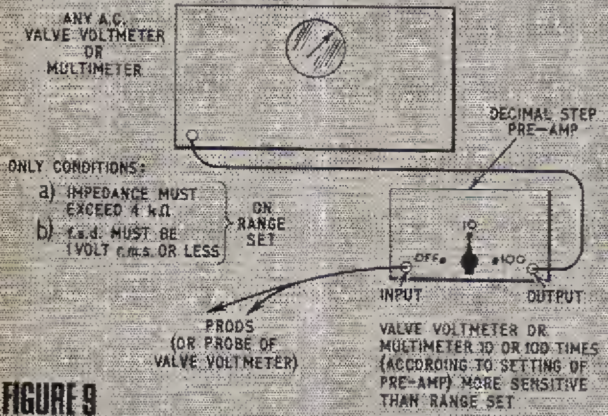


FIGURE 9

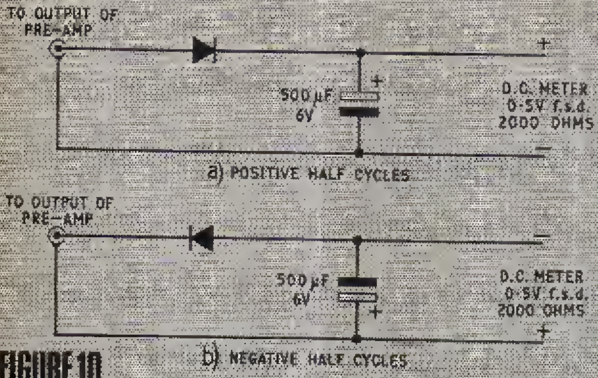


FIGURE 10

Fig. 8. Decimal step pre-amplifier used to increase Y-deflection sensitivity of an oscilloscope

Fig. 9. Method of increasing the sensitivity of an a.c. voltmeter

Fig. 10. Use of decimal step pre-amplifier to convert 0·5V f.s.d. meter to 5mV/50mV f.s.d. a.c. voltmeter

on low d.c. ranges may therewith be converted to sensitive a.c. "valve" (transistor) voltmeters. There are no impedance matching conditions to be observed in this case, provided that the meter and rectifier circuit impedance is much greater than the output impedance (500 ohms) of the pre-amplifier. Multimeters having a resistance of 4,000 ohms per volt and upwards on the d.c. ranges can thus be operated from the pre-amplifier output.

Fig. 10 shows a suitable rectifier circuit to make the meter indicate peak volts of one polarity. Reversing the diode and the connections to the meter makes it indicate peak volts of the other polarity. In the case of arbitrary non-sinewave signals applied to the input of the pre-amplifier, where the peak voltages on negative and positive half cycles may differ, corresponding different readings will be obtained.

Taking the Caby Model B20 multimeter as a typical example, we have a lowest d.c. voltage range of 0·5V f.s.d., 2,000 ohms impedance, available on the meter. This is satisfactory in every way for connecting to the output of the pre-amplifier via the rectifier circuit of Fig. 10 which may be built into the coaxial connecting cable fitting PL2 on the pre-amplifier at one end and the multimeter terminals at the other end. The multimeter is therewith an a.c. voltmeter giving full scale deflection for 50mV peak or 5mV peak (gain 10 or gain 100 settings respectively) applied to the pre-amplifier input, an excellent sensitivity. Moreover, the arrangement is usable not only at power mains frequency, but at any frequency over the entire hi fi audio range. If measuring positive and negative half cycles separately where these differ, it is important to remember that the pre-amplifier inverts the signal in the gain 10 setting, but not in the gain 100 setting.

Table 1 lists some typical audio applications of the pre-amplifier. These certainly do not require the accurate decimal step and stabilised gain, but it is, in the interests of universality, necessary to point out that the pre-amplifier is in every way suitable for such applications as well.

THE VEROBOARD SYSTEM

Although orthodox printed circuit panels would be used in commercial systems of this nature wherever the production numbers are at all high, the *Veroboard System* is more suitable for small production numbers and especially for amateur and experimental equipment.

The VB2503 panel is made of plastics card drilled over its entire surface with a square grid of holes having 0·15in spacing, 16 holes across the width and 21 holes along the length. The rear side only is fitted with 16 parallel strips of copper, each respectively running along one row of 21 holes along the length of the panel. These strips are thickened and gold-plated at one end, where the whole card plugs into a linear 16-contact socket.

Components are arranged on the front side (Fig. 2 and Fig. 4), where there are no copper strips; the wire ends are pushed through holes at respectively convenient positions, soldered with a spot of solder at the rear where they pass through the copper strip, and then cut off close.

If alterations are subsequently required, melt the solder by applying an iron at the rear while pulling the component wire with pliers from the front. Then jab a piece of bare tinned copper wire through the hole

continued on page 115

PRECISION DECIMAL STEP PRE-AMPLIFIER *continued from page 109*

rapidly while again applying the iron, to clear the hole of solder before inserting the new component.

It is advisable to use a miniature pencil-bit iron, e.g. of the 6 volt 10 watt variety. The copper strips on the cards take solder extremely rapidly and readily, so that it is possible to work quickly enough to prevent damage to transistors.

In the diagrams, Figs. 2, 3, 4, and 5, the rear copper strips have been numbered 1 to 16 from left to right as viewed from the front (components side) of the cards, and the 21 holes along any strip have been lettered A to U commencing from the socket end. Any hole can thus be specified by the corresponding number and letter combination. Where straps are shown between two holes these are simply short pieces of bare tinned copper wire cross-connecting different copper strips. Some of these straps are also located on the rear side, directly over the copper strips, as shown in Fig. 3 and Fig. 5.

The copper strips are to be interrupted at all the specified holes on the rear side of each card. Messrs. Vero Electronics sell a special hand awl, Cat. No. VB3011, for this purpose. This consists of a wooden tool handle carrying a small drill shaft of somewhat greater diameter than the width of the copper strips. A blunt pin extends at the front end of the drill shaft and exactly fits the holes in the circuit card. The drill is therewith held central while it scrapes the copper strip away at the desired point.

The two circuit cards, together with their associated sockets, can be accommodated quite conveniently in a box measuring approximately 8in by 5in and 2¼in deep. Fig. 7 shows the arrangement of the items inside the box and also details the interboard wiring.

Next month: the concluding part of this article will discuss some of the principles involved in the design of this pre-amplifier; factors which determine the input impedance will be explained and practical information given for adjusting this to some other value

---

Contributed Articles

The Editor will be pleased to consider for publication articles of a theoretical or practical nature. Constructional articles are particularly welcome, and the projects described should be of proven design, feasible for amateur constructors and use currently available components.

Intending contributors are requested to observe the style in our published articles with regard to component references on circuit diagrams and the arrangement of the components list.

The text should be written on one side of the paper only with double spacing between lines. If the manuscript is handwritten, ruled paper should be used, and care taken to ensure clarity, especially where figures and signs are concerned.

Diagrams should be drawn on separate sheets and not incorporated in the text. Photographic prints should be of a high quality suitable for reproduction; but wherever possible, negatives should be forwarded.

The Editor cannot hold himself responsible for manuscripts, but every effort will be made to return them if a stamped and addressed envelope is enclosed.