DC CONTROL OF ANALOGUE SIGNALS

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Useful techniques and circuit ideas

Despite the increased use of digital integrated circuits in analogue audio devices, d.c. control is still widely used and has hundreds of applications.

CONTROL of an analogue signal has traditionally been by way of a standard potentiometer, whether this be an audio volume control, tone control, or a more complex control such as is used on a mixing desk or a music synthesiser.

An increasingly common requirement in today's Hi-Tech electronics systems is d.c. or remote control of analogue signals. The earliest and most common application of analogue signal control using a d.c. control potential is of course in the domestic TV receiver. This requirement came about due to the market needs for remote control TVs.

Since the TV market is so vast, semiconductor manufacturers were quite happy to invest large sums of money generating dedicated i.c.s particularly for this purpose. Most of these i.c.s however contain a lot more than just the d.c. control circuits and in some cases about half of a modern TV. Only relatively recently have manufacturers released useful i.c.s for the general electronics industry. It is not the purpose of this article to explain these i.c.s and their uses – most of their information can be obtained from the manufacturers' data sheets. This article is mainly concerned with demonstrating that for many cases simple d.c. control can be achieved using standard, low cost, easily obtainable, discrete components.

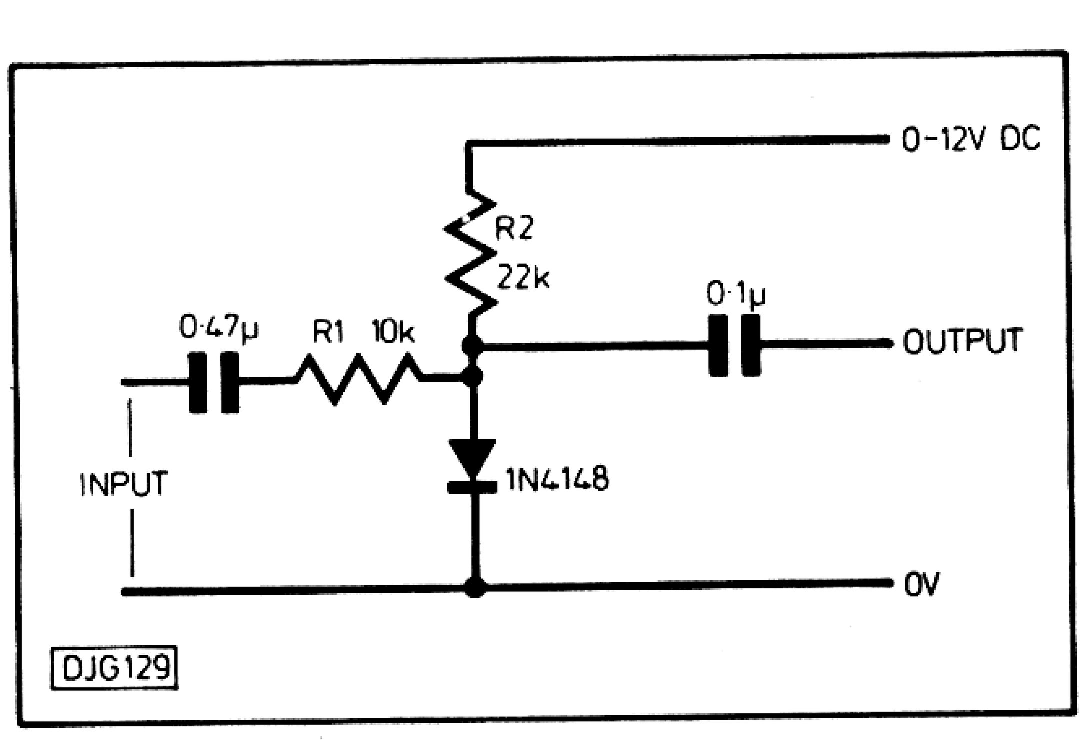

Fig. 1. *Diode control*

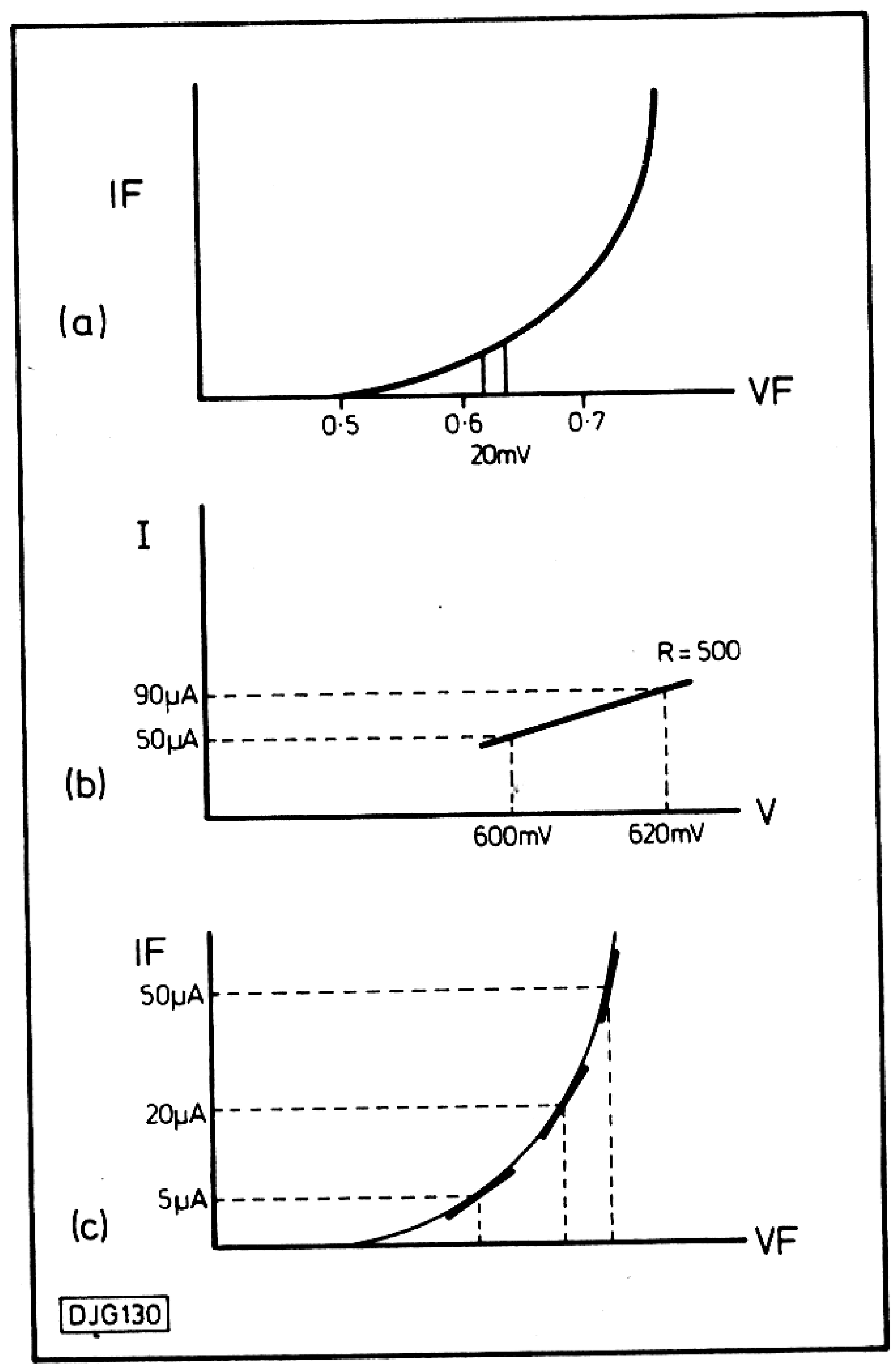

Fig. 2. *Characteristics*

Nowadays, with even the simplest of electronic gadgets, a microprocessor is often at the heart of the system and this often needs to control external analogue signals. It is also undesirable to route audio signals around in the same box as a micro due to the chances of picking up spurious digital noise.

Using a d.c. voltage to control the signals' parameters allows the designer to position the controls where he wishes on the front panel.

The most difficult problem of d.c. controlling a signal is that of distortion. The signal itself to be controlled is a varying signal and hence will have a tendency to modulate the control voltage and then in turn modulate itself.

Fig. 1 shows a very simple method of gain control using a diode as a variable resistor. It may seem strange to apply the audio signal directly across a diode in this manner as one would imagine the diode to simply clip off one half cycle. This is true for large signals, however, if the signal level is kept at a fairly low amplitude, typically less than about 10mV RMS, then the diode acts as a fairly linear resistor. Fig. 2 shows this, and it's clear that varying the diode's current will cause a change in the slope of the V/I characteristics and therefore a change in its forward resistance. The value of the diode's forward resistance is approximately 25/If where If is the diode's forward current in milliamps.

The distortion generated by this circuit is surprisingly low at around 0.2% and the amount of attenuation is determined by the ratio of R1 to the diode's forward resistance. Typical attenuation levels range from 0db with zero control current to better than −50db dependent upon the control current and the value of R1. Varying the control potential will vary the current through the diodes and hence alter their forward resistance.

The actual amount of distortion produced is very dependent upon the signal amplitude and is predominantly 2nd harmonic in nature. If a larger signal than 10mV RMS is to be controlled, then two diodes may be used as in Fig. 3. This circuit gives some measure of distortion cancellation allowing a signal of up to 40mV RMS to be controlled with less than 0.2% THD this time predominantly 3rd harmonic. As a matter of interest a 50% reduction in signal amplitude causes a 5 fold reduction in distortion.

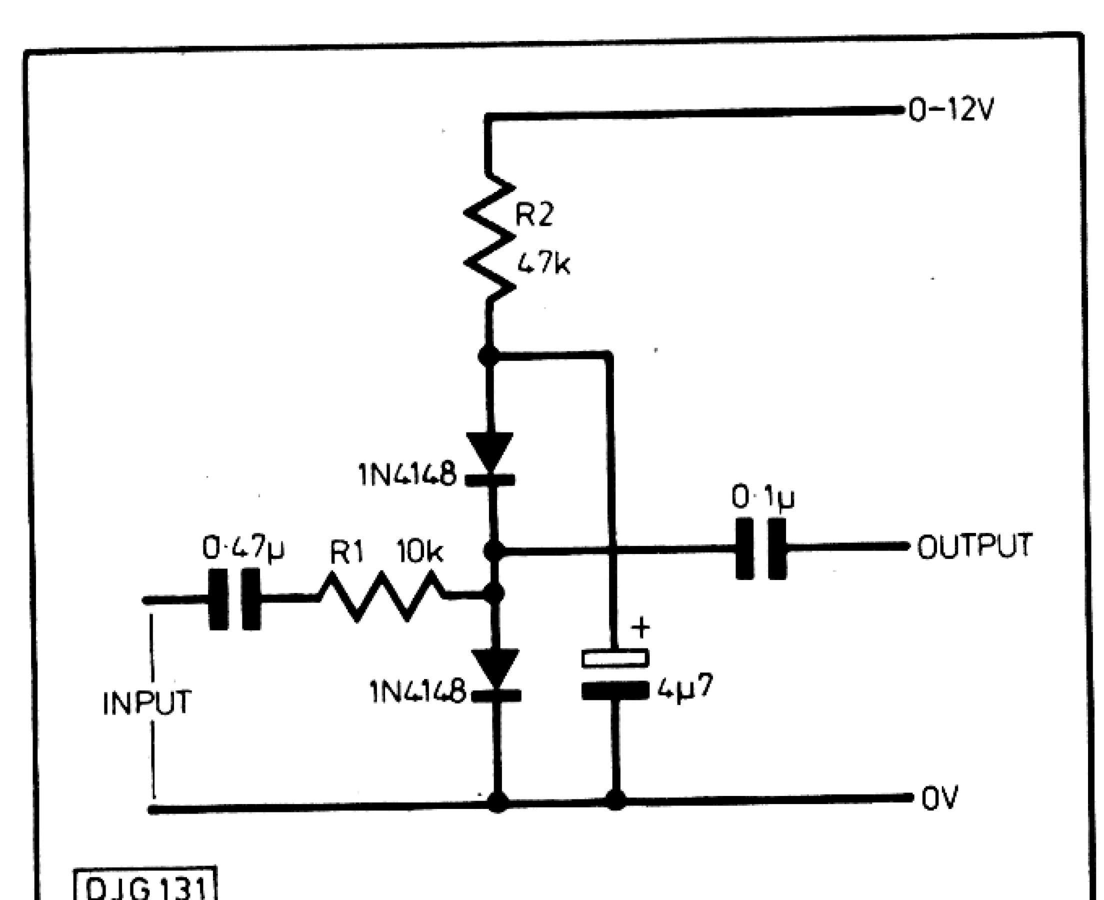

Fig. 3. *Distortion cancellation*

Still further reduction in distortion and greater signal handling can be achieved by using two diodes in series in place of each diode as in Fig. 4. This circuit will accept up to 80mV RMS and there's no reason why this technique cannot be extended further by adding more diodes.

SERIES TYPE ATTENUATORS

The circuits so far described are all shunt attenuators, however a series type attenuator can be built and a common type is shown in Fig. 5. Again this circuit will only work satisfactorily with low levels of signal at around 10mV. Since

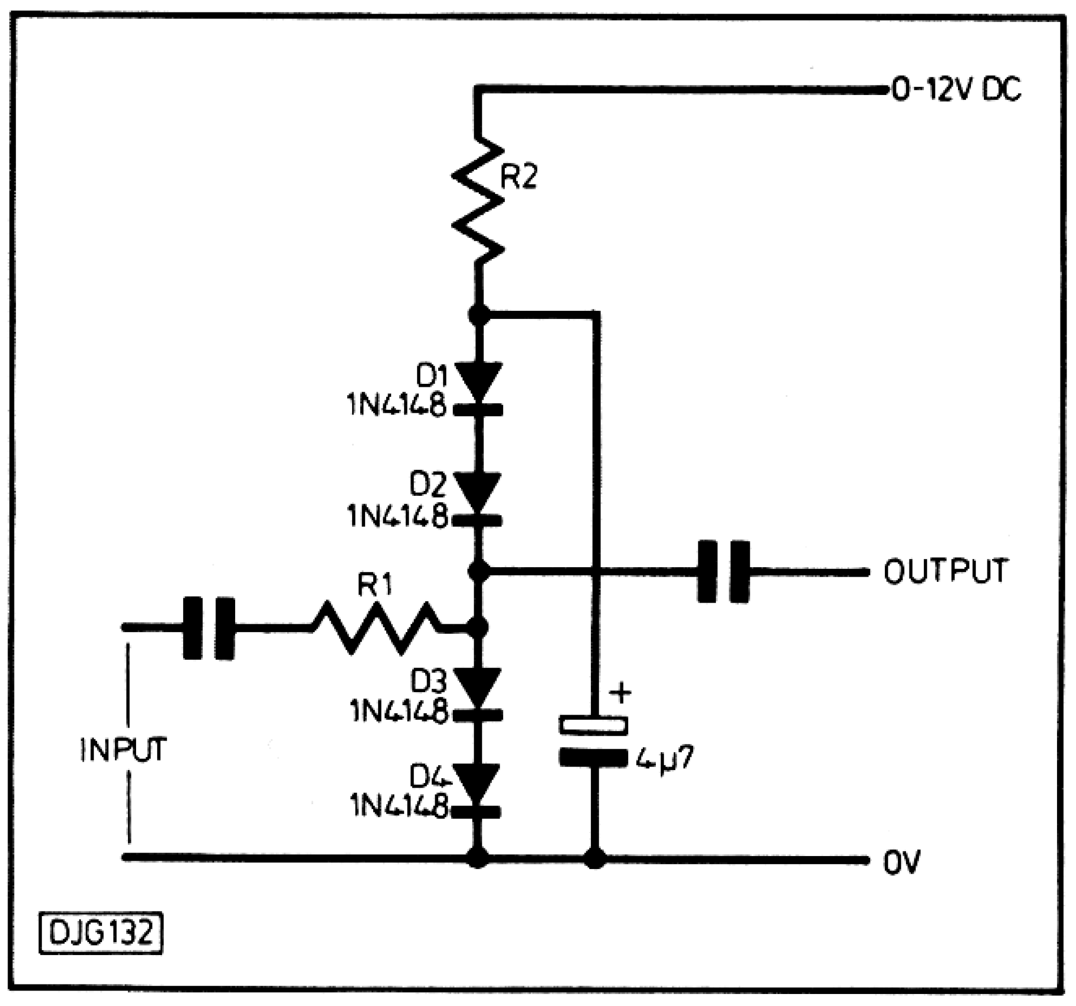

Fig. 4. *Further cancellation*

both diodes act as variable resistors, there is a different level of signal amplitude across each diode and hence the distortion cancelling properties are not as good as in the shunt type.

Fig. 6 shows an alternative series circuit, one which I prefer as the signal level across each diode is equal and therefore distortion cancellation occurs.

It's now worth looking at the advantages and disadvantages of the series versus the shunt type.

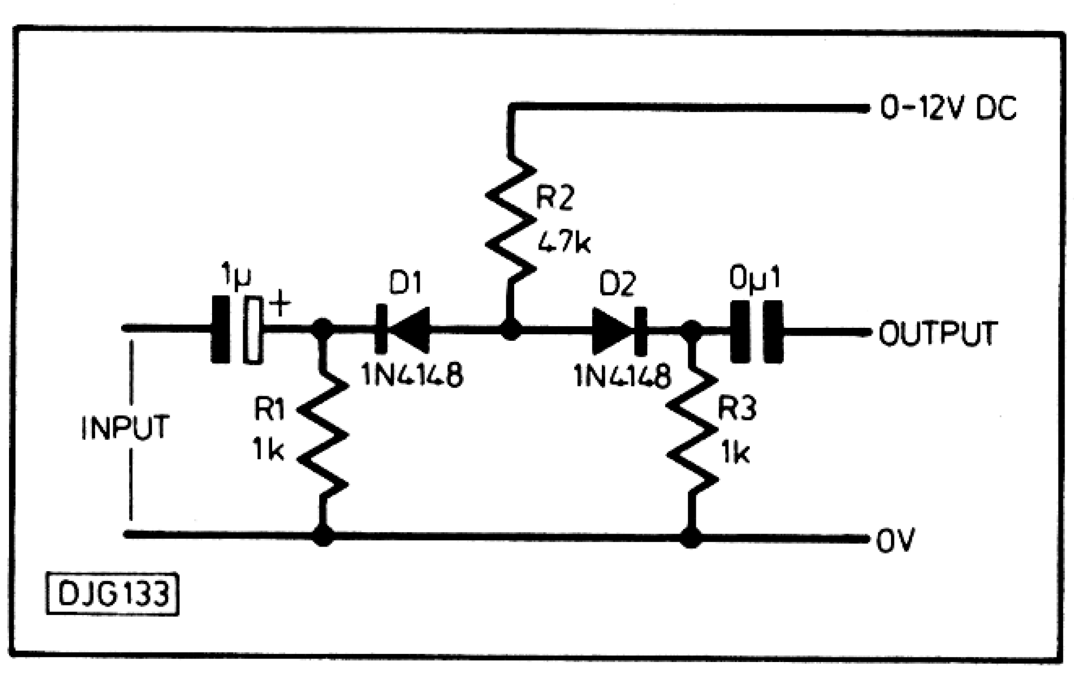

Fig. 5. *Series attenuator*

The shunt type has the greatest signal handling capability provided the signal across the diodes is kept below the levels described earlier. This is because the input signal during attenuation appears across R1 and only the output signal appears across the diodes. The polarity of the shunt attenuator is positive ie, an increase in control voltage will cause an increase in signal attenuation. The shunt type however does have only a limited amount of attenuation capability and

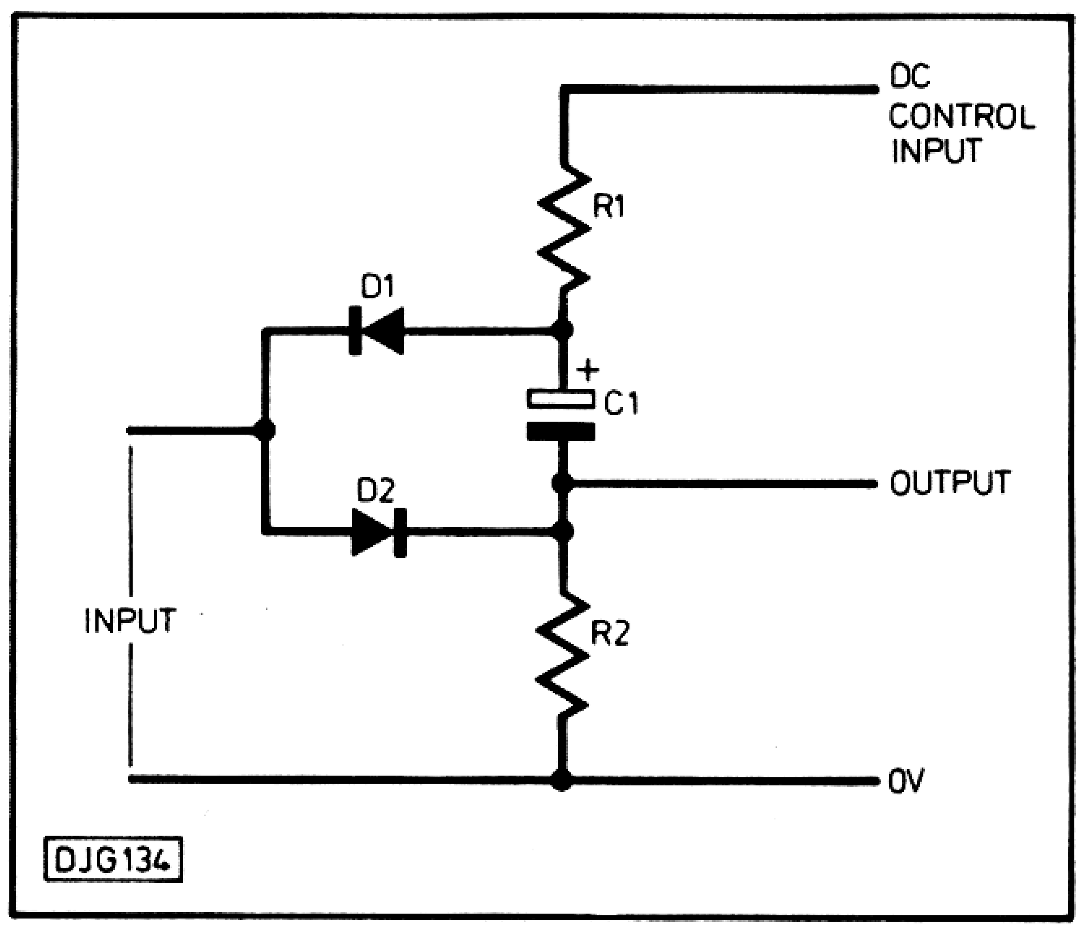

Fig. 6. *Preferred circuit*

greater attenuation can only be had by cascading two or more stages.

The series type on the other hand has a relatively poor signal handling capability. At high levels of attenuation the input signal appears across the series diodes. Therefore unless the input is kept below the previously described levels, distortion will be produced. It does however have the capability of a much greater level of attenuation typically better than 80db and has a negative polarity ie, increasing the control voltage reduces the attenuation.

The polarity can however be reversed as shown in Fig. 7 which also shows how the properties of a shunt type can be combined with those of a series type to produce an attenuator with all the desirable aspects of each circuit. The signal is first attenuated by the shunt circuit with its good signal handling properties and then it meets the series type at a much reduced level. The series circuit then provides the level of attenuation without any overload problems.

Fig. 8 shows a simple d.c. controlled tone control. This circuit will provide up to 12db of bass boost and 15db treble cut dependent upon the d.c. control voltages. The input will accept audio at around 300mV RMS, the output level being around 80mV. The amount of bass boost provided is dependent upon the relative values of R1 and R2 and the turnover frequency dependent upon the time constant of R1 + R3 and C3. The treble turnover frequency is dependent upon the time constant of C5 and R3.

Fig. 9 shows how the diode attenuator circuit can be used as an amplitude modulator and so produce at a very low cost the well known 'Tremelo effect'. T1 is connected as a phase shift oscillator and generates a low frequency sinewave, this is then impressed upon the d.c. control voltage to modulate the audio signal.

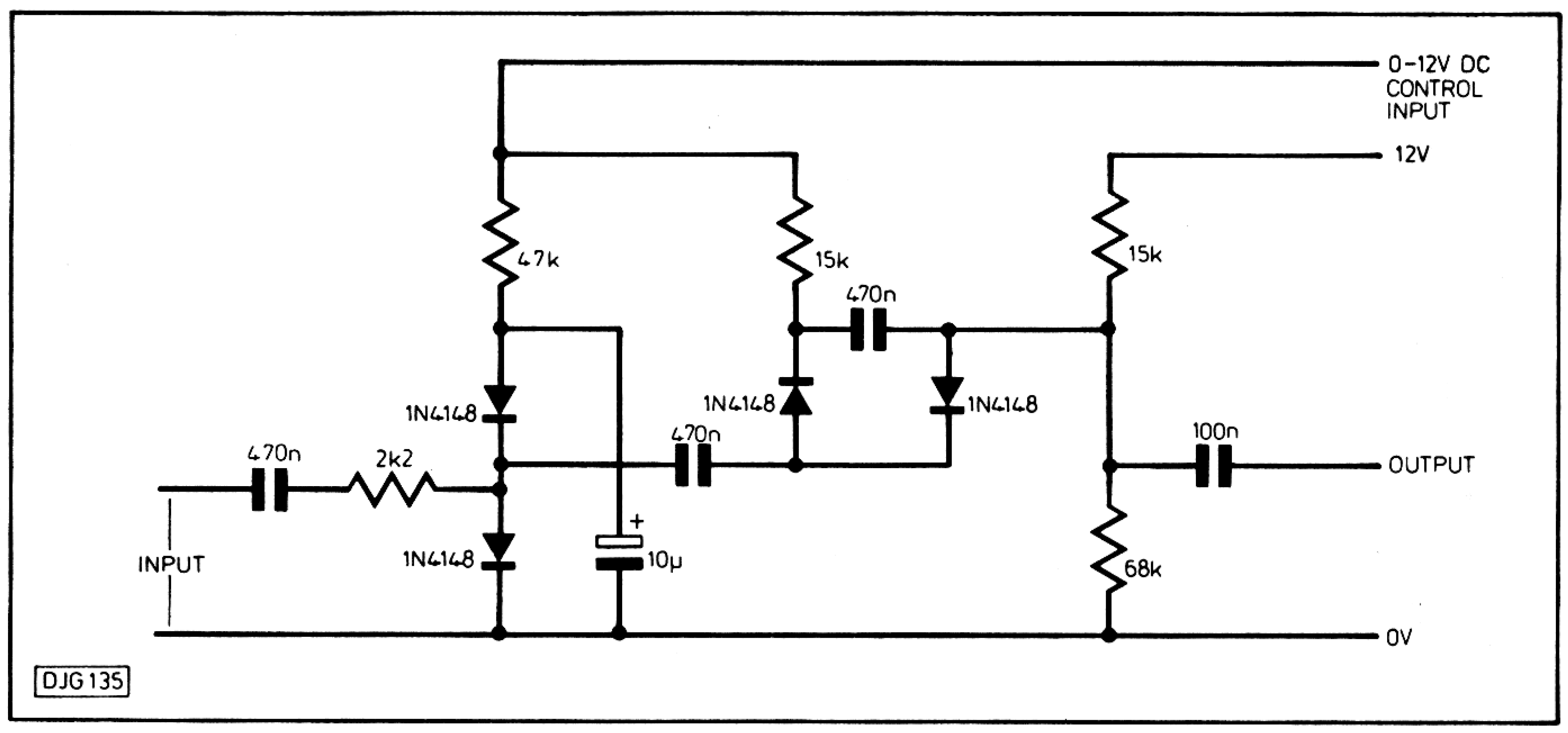

Fig. 7. *Combined short and series circuit*

Those keen eyed constructors may have noticed that the phase shift oscillator has four time constants instead of the usual three. This has the added advantage that four time constants each

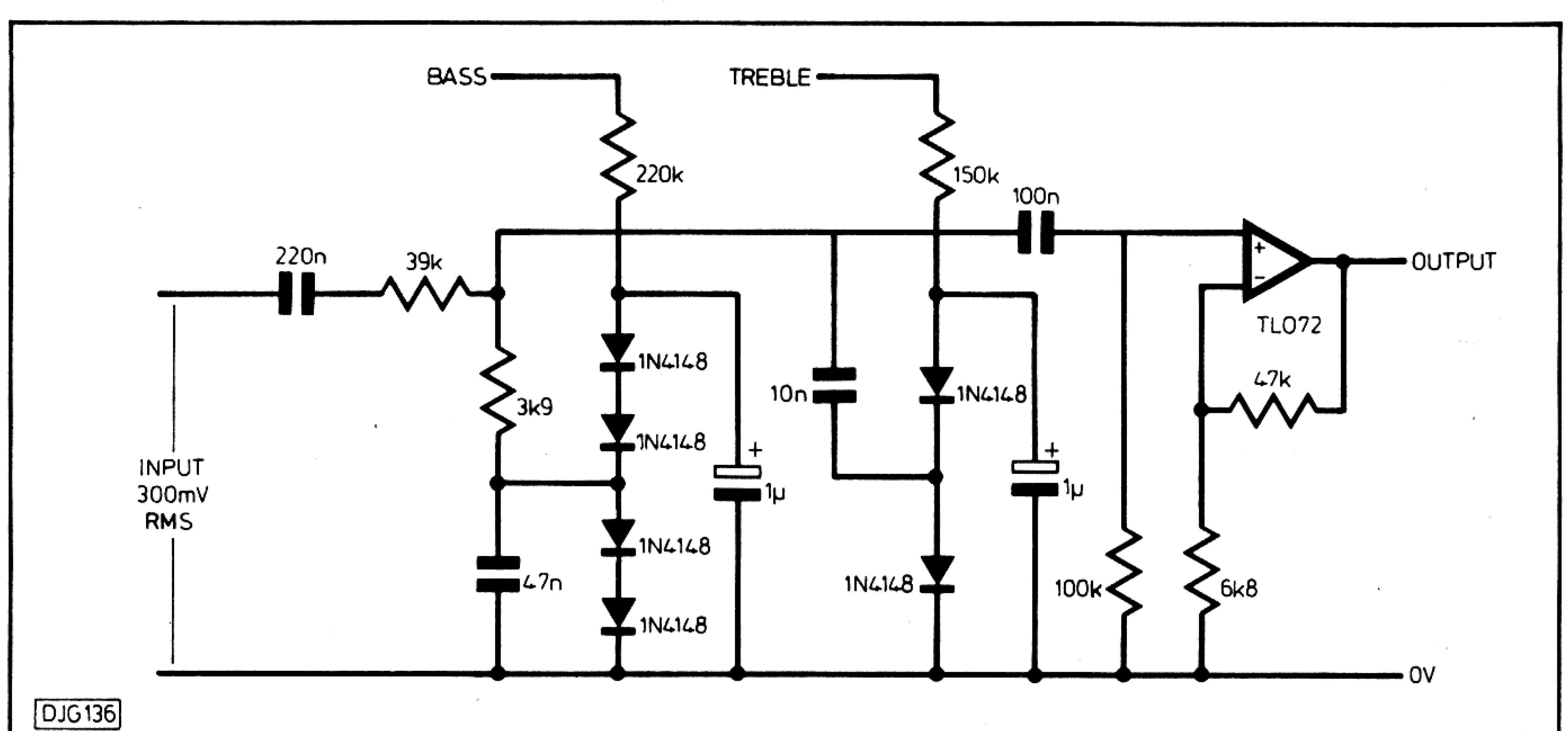

Fig. 8. *D.C. controlled tune control*

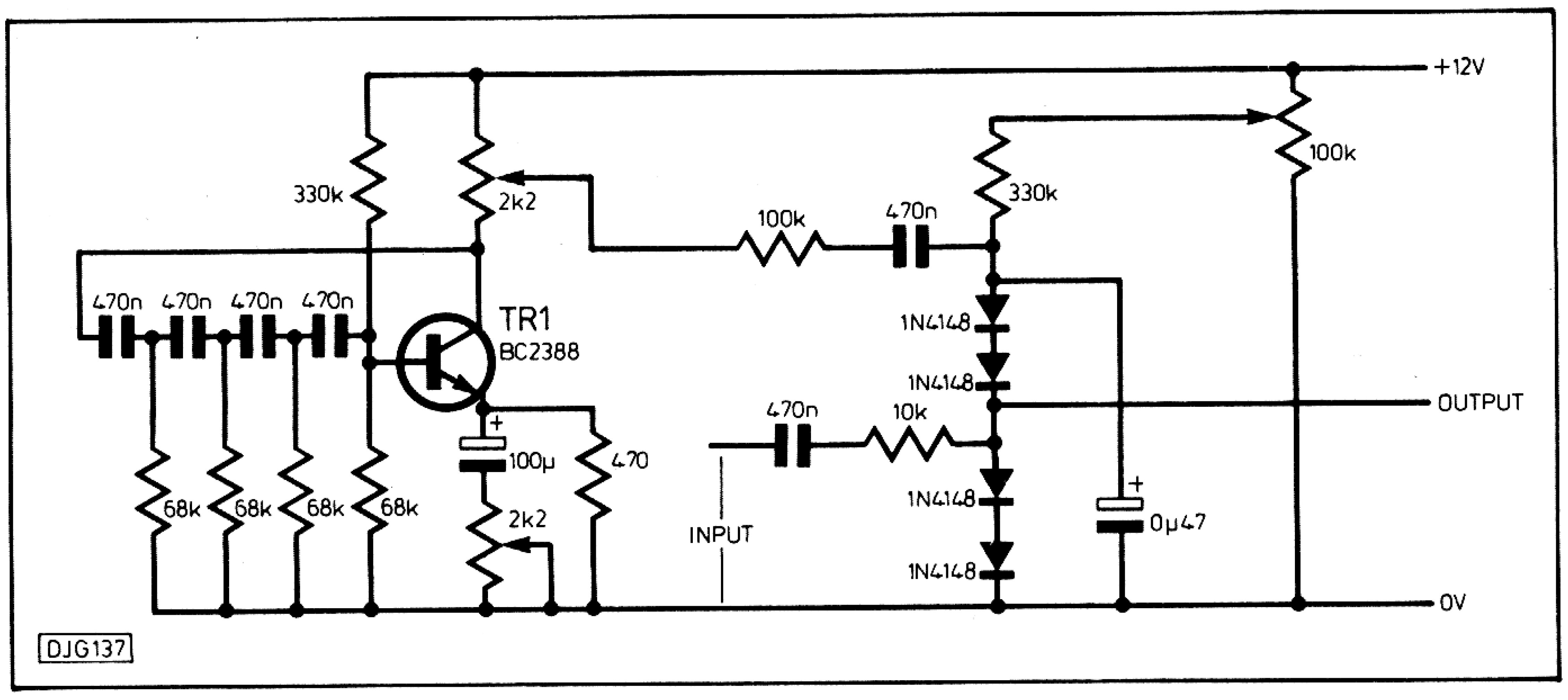

Fig. 9. *Amplitude modulator*

contributing only 45 degrees phase shift give less overall attenuation than the more usual three at 60 degrees. TR1 therefore does not have to supply as much gain and hence it is much easier to control its gain more accurately.

The circuit shown in Fig. 10 is of the familiar 'All Pass' filter or constant amplitude variable phase filter. It is used in several different musical effects units ie the 'Phasor' and also the 'Flanger'. The phasor unit consists of two stages cascaded and hence gives a maximum phase shift of 360 degrees. The flanger unit, however, consists of at least six stages cascaded and sometimes even more. The effect of this phase shifted signal when added to the original signal is to produce a series of alternate signal additions and cancellations across the frequency spectrum. This circuit is often called a comb filter due to the comb-like frequency response.

The main problem with each of these circuits is that to produce the required sound effects the phase shift has to be variable under user control. With six or more stages it is impractical to have a six gang pot and therefore d.c. control is essential. One or two circuits have been published in magazines in the past and the most common method of adjustment appears to be by way of Light dependent resistors (l.d.r.s) in place of R1 and l.e.d.s placed close to them. The control voltage is used to drive the l.e.d.s and therefore vary the l.d.r.s resistance. l.d.r.s are quite expensive and it's often thought a rather clumsy way of providing control.

Some commercial units use FETs to act as the variable resistor element, these too are relatively expensive although less than l.d.r.s but due to the very large spread in gate potential, these FETs must be selected to match their characteristics closely.

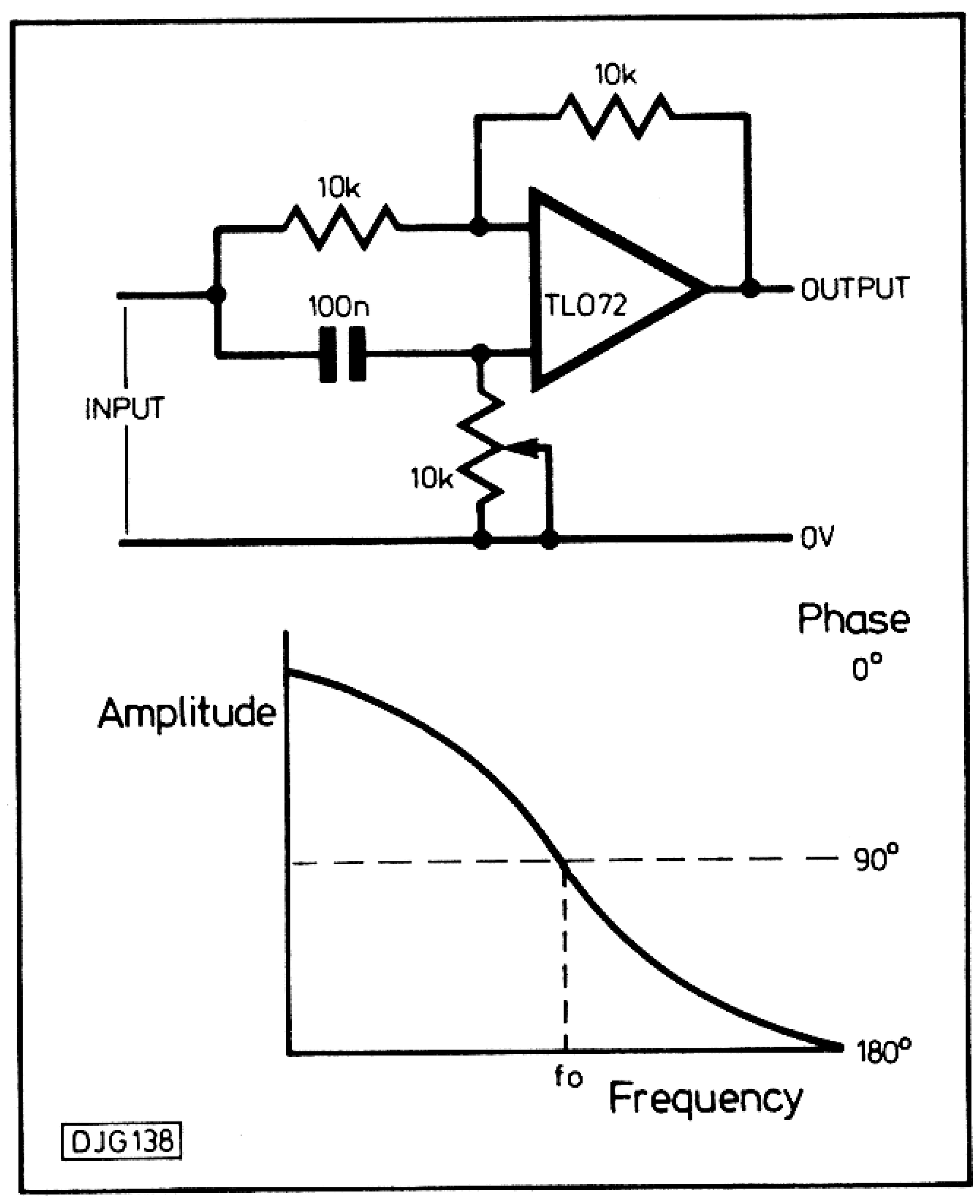

Fig. 10. *'All Pass' filter*

Fig. 11 shows how the shunt diode attenuator of Fig. 3 can be used as a very cost effective alternative to l.d.r.s or FETs. The diodes, unlike FETs, do not have to be matched and as many stages as one wishes can be cascaded.

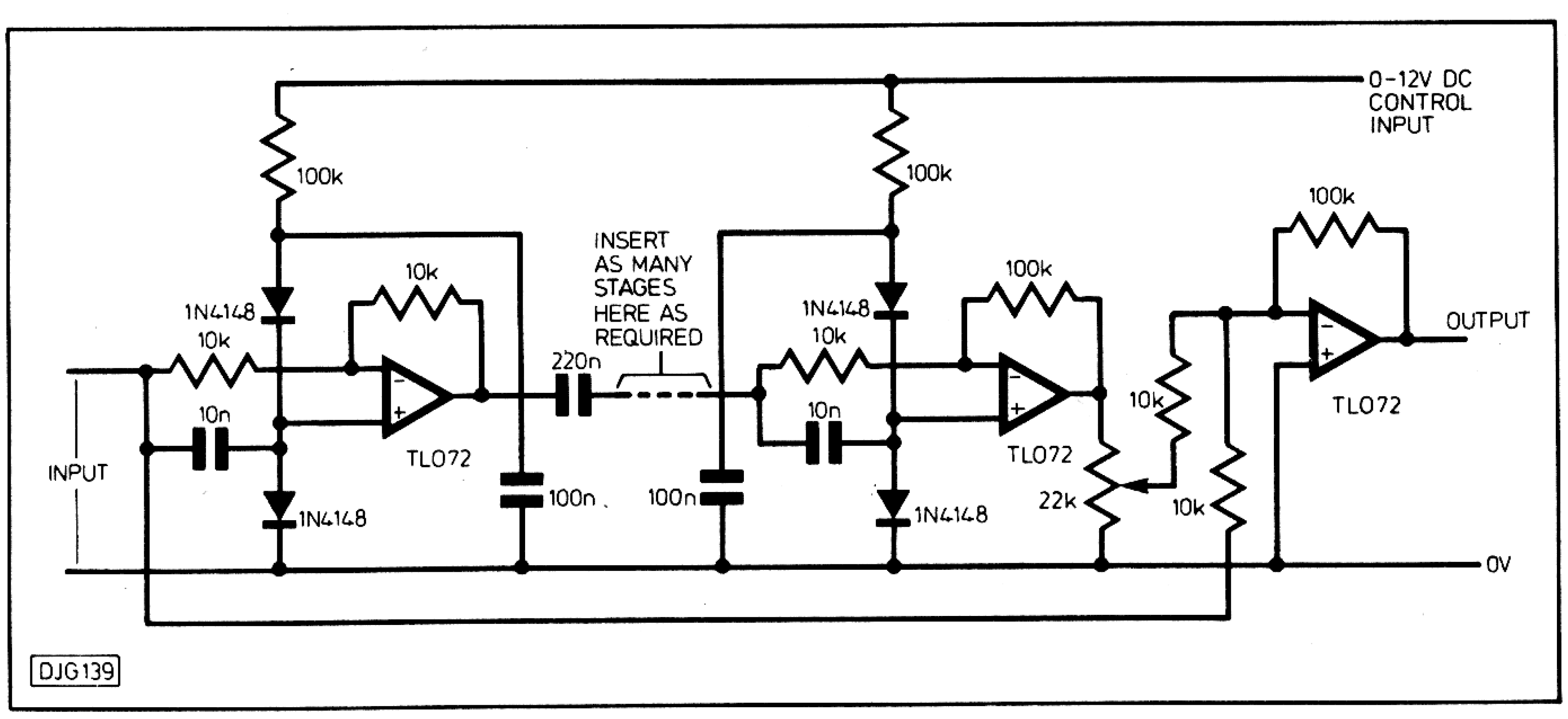

Fig. 11. *Alternative to l.d.r.s.*

The drive current to the diodes is quite small, just a few tens of micro-amps, therefore they can easily be driven directly from an op-amp connected as either a sinewave phase shift oscillator or as in Fig. 12 as a linear ramp generator.

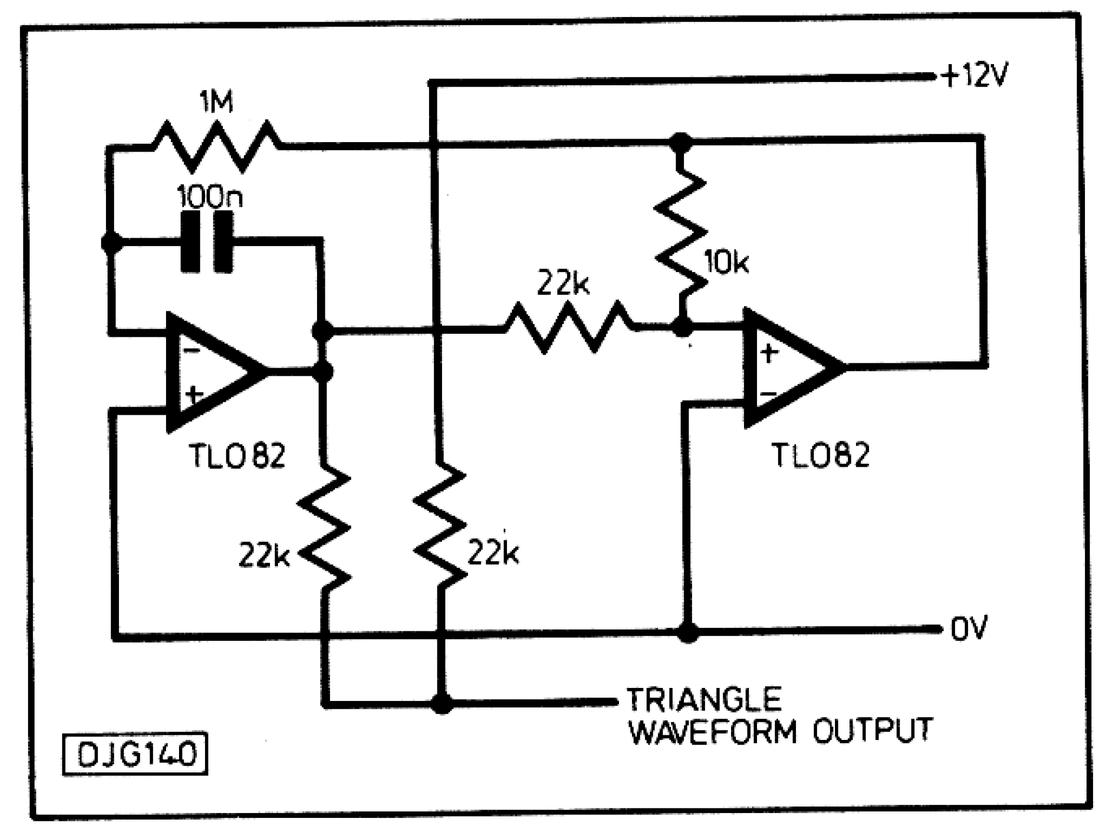

Fig. 12. *Linear ramp generator*

It should also be pointed out that the purpose of C2 in Fig. 1 is to decouple audio such that both diodes see the input signal equally. Therefore it should not be made unnecessarily large otherwise it will tend also to decouple changes in the control voltage. PE