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VCT AN INVENTION THAT WILL CHANGE THE FACE OF ELECTRONICS

SOME MONTHS AGO we ran a short item about a device totally unknown in this country at that time - the VCT or Voltage to Current Transactor. Well now we hope to make it considerably less unknown. The VCT will get get its commercial launch from Texas Instruments early in 1977, no doubt accompanied by the usual choir of angels and 200 piece brass band.

So before all the shouting begins we went to talk to the co-inventor, Professor W.Gosling of Bath University where the device was initially developed. If you're sitting comfortably we'll begin!

The basic op-amp has been with us since the days of the valve, and when semiconductors crept up on us, it was simply re-designed to use transistors. This, in the opinion of many designers, means that the advantages of transistors are not being fully exploited.

BASIC IDEAS

One of the better improvements to the basic op-amp was the comparator input designed by Carl S. Brinkler - a name to which we shall return - and patented in April 1965. However Mr. Brinkler was still dissatisfied with the op-amp and some years ago began discussions with Professor Gosling, with a view to producing a totally new circuit block. The basic guidelines were finally set as being that

1. No feedback should be needed to stabilise the device by limiting the high frequency response, or to define the stage gain.
2. Both the input and output ports must be totally floating - a true four terminal device. This leads to much greater freedom with respect to the output - it can quite simply be fed into anywhere!
3. The output should be a constant current source i.e. very high impedance. Then, should a voltage output be required at any time, a resistor need only be inserted across the port.

TEXAS AND THE PROTOTYPES

In 1974 Texas Instruments authorised Carl Brinkler to undertake research into producing such a device. Because of the scope and magnitude of the task, it was to be a joint undertaking with Bath University i.e., Professor Gosling. In the autumn of 1974 the microcircuit design was breadboarded up for the first time with discrete components, and early in 1975 the first I.C.s rolled out of the ovens. The first vast improvement over the op-amp to become apparent was the slewing rate, up to 20V per microsecond, as compared to 0.5V/microsecond for the 741.

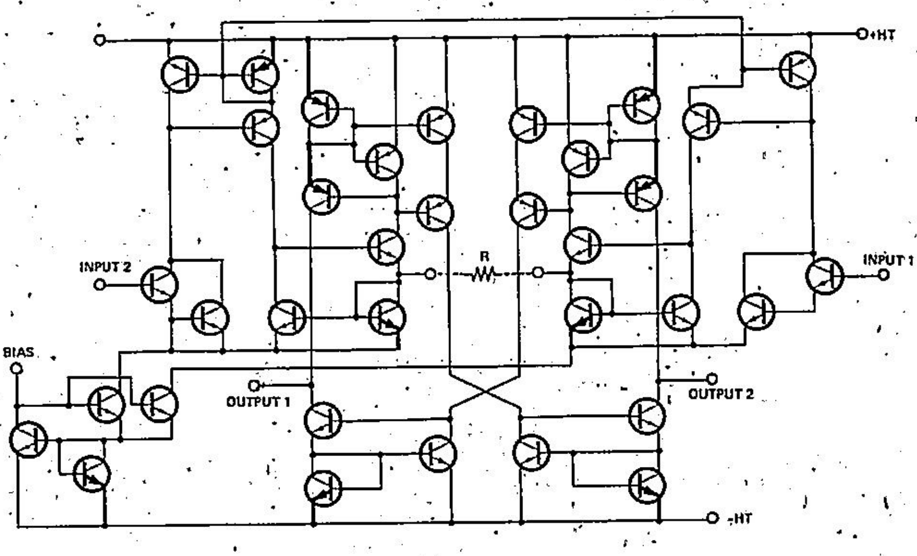
The offset on these prototypes was ≏10mV due to the layout not being totally symmetrical. Production models, when they appear, will have a much much lower offset. Up to this point in the proceedings, the project had been running on a shoe-string. But with the prototypes showing this incredible potential, Texas whipped the whole show off to Dallas for development. They feel the VCT is the greatest advance in circuit design for a long time, and we have to agree with them.

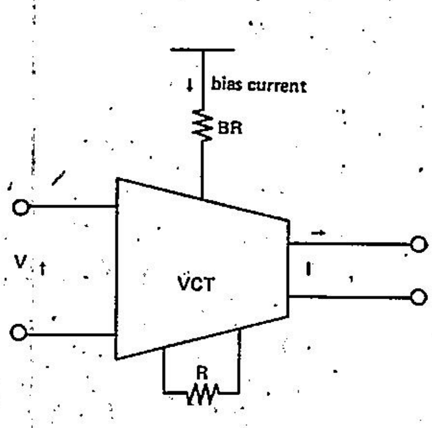
ABILITIES IN CIRCUIT

Let's take a look at what the VCT will do. Figure 1 shows the internal circuit of the Mark 1 VCT. The thick lines represent multiple emitters, and these provide the current gain. You may recognise the current mirrors around the top centre of the circuit.

The agreed symbol for the VCT is shown below, the circuit is that used

Fig. 1. Internal circuit of the prototype VCT. The 'R' in the middle is external.





The agreed symbol for VCT.

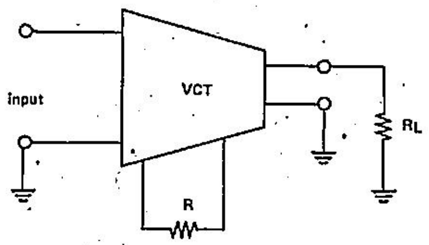
VCT

for all linear applications. For a voltage input, we get a pure constant current output. Both input and output impedances are very high, around 10s of Megohms in the production devices.

There is a fixed ratio between V_{in} and I_o, which is set by one fixed resistor R. i.e. $I_o = k\,1/R\,V_{in}$. The constant k can be designed to be any value - it will be four in the Texas VCTs. A bias current is applied down BR, and the device can only output twice as much current as it draws through BR. Early devices will be 20mA output VCTs, but later marks will be up in the amps range. A ±15V rail is used with the VCTs, and a 13V signal is quite permissable!

Some circuits now; for instance an amplifier:

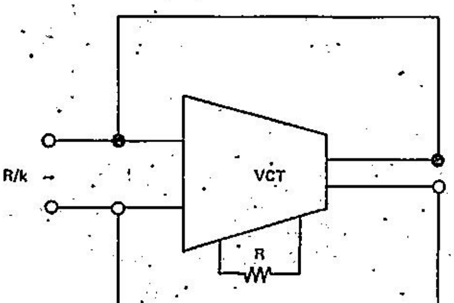
Non-inverting:



VCT as an amplifier.

Voltage gain = k. RL/R

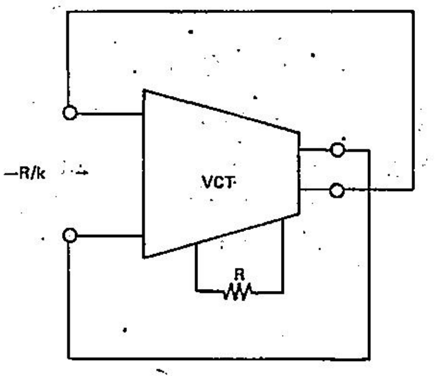
The simplicity of gain inverting arises because the output port naturally has a fixed phase relationship to the input. Since we get a current out for a voltage in, a VCT connected thus:



VCT as a simple resistor.

will look like a resistance, value R/k ohms.

Consider however a device cross connected:



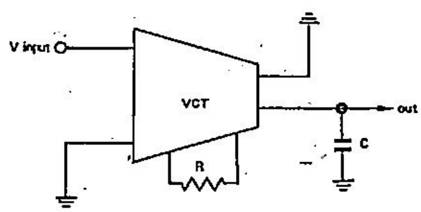
VCT working as a negative resistance.

What we have now, looking in at the input terminals, is no less than a negative resistance! i.e.

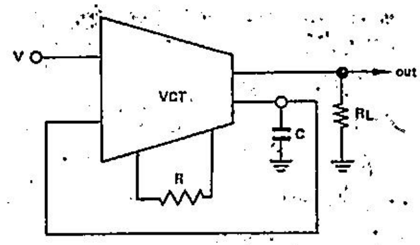
$$V_{in} = -\text{const.}I_o.$$

What's more, the transfer characteristic is perfectly linear!

Applications are literally infinite. Anything an op-amp can do, so can a VCT - only usually it does it better! For instance an integrator:



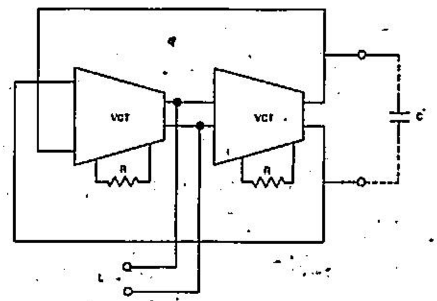
At point A we have $\int V_{in}\,dt$ since the output is a constant current which follows the input voltage. If we feed back this integral to the input so:



VCT differentiator.

the output will be the differential of V_{in}.

Gyrators are by now quite common place, but what about one which can reach inductor values of 10s of Henrys and with a Q of well over 100? Easy!

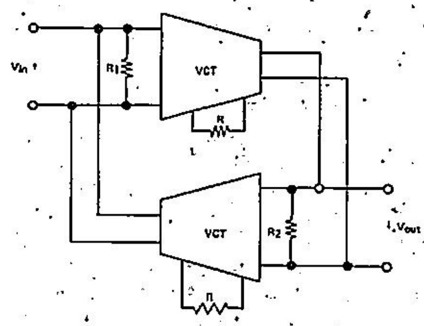


A VCT gyrator.

Values of Q up to 200 have been achieved experimentally. This circuit introduces the concept of using two VCTs together. Texas are packaging the VCT in a 16-pin DIL dual package. There are more pins to a VCT than a 741, since we have those already mentioned, plus a centre tap on the output which is not always used, but extends the versatility.

AMAZING GRACE

The application we found initially most amazing is the VCT's ability to replace a transformer, better than a transformer! All transformers exhibit some power loss, but this circuit has a selectable loss factor, which naturally can become a *gain* if so desired.



VCT as a transformer.

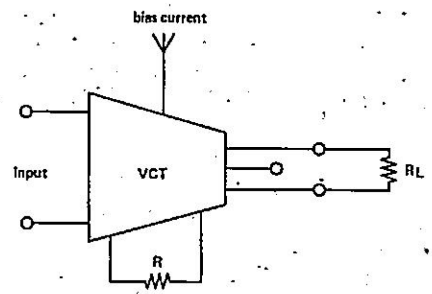
Transformer Ratio = $(R_1/R_2)^{1/2}$.

Choose R such that $R^2=R_1R_2$ to give no loss/gain in circuit i.e. a perfect transformer.

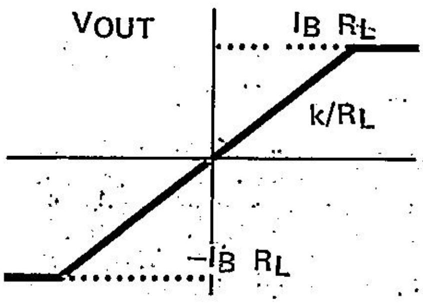
The GPO are looking at this application with a view to replacing all those messy coils in telephones.

NON-LINEAR

We will consider just one non-linear application to show it can be done - that of a limiter. Since the VCT can output only 2x bias current with



we will get a characteristic



very simply indeed with only two resistors.

GAINS FROM LESS

It is apparent from the preceeding circuits that one of the biggest gains when using VCTs, is in reducing external component count over a similar op-amp or discrete circuit. In industrial applications this will lead to less P.C.B. design and assembly complications, with resultant reduction in costs.

Another gain is the fact that when used as an inverting amp, no input resistor is used to drop the signal, as it is in op-amp circuits. In these circuits, since the input is usually a virtual earth, most of the signal is dissipated in the resistor, with a resultant poor signal-to-noise ratio upon amplification at the output. With VCTs no resistor is required, and this gives a distinct improvement in S/N ratio, with the attendant gain in dynamic range.

THE PRICE OF A FUTURE

One question remains - how much? Well, this depends entirely on Texas Instruments, and the marketing policy they persue. No doubt the price will be high at first, falling as the volume of sales climbs, as it surely must. Interestingly, the VCT occupies only half the chip area of a 741 op-amp, but whether this affects pricing remains to be seen. We'll keep you informed of developments, as we're convinced you'll be hearing much more of VCT in the years to come. ●

OUR THANKS and congratulations to Professor W. Gosling of Bristol University, who provided the information for this article.