Linear Voltage Controlled Oscillator

A novel configuration which utilizes an i.c. transistor array and is capable of a linearity better than 1% per MHz

by J. L. Linsley Hood

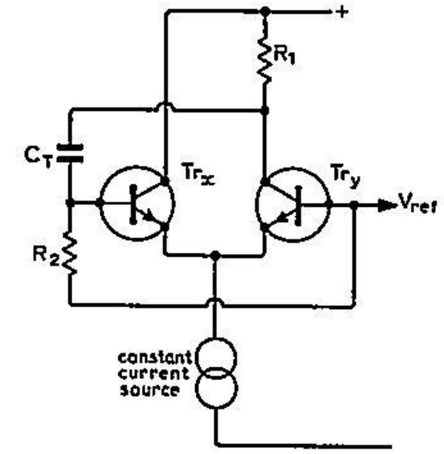


Fig. 1. Multivibrator configuration for a free running square-wave generator.

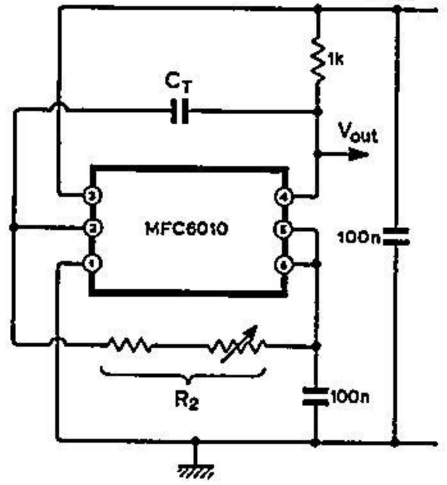


Fig. 2. Square-wave oscillator with a high long term stability. Operation is up to at least 20MHz.

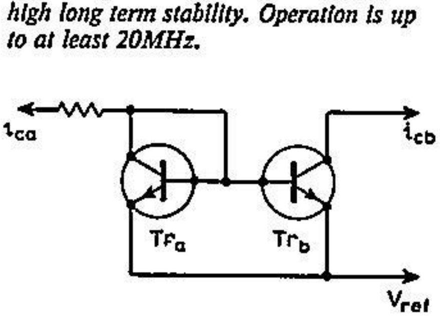


Fig. 3. "Current mimic" circuit which can be used to substitute the timing resistor, R_2, in Fig. 2.

The growing use of phase locked loop systems in applications such as very high quality f.m. demodulators, in which a high degree of linearity between input frequency and output (control) voltage is sought, has focused attention on the characteristics of the available voltage controlled oscillators (v.c.os) — the linearity of the phase locked loop is mainly determined by, and cannot be better than, that of the v.c.o. contained within it. However, although the availability of a very linear v.c.o. system would allow improvements to be made in phase locked loops built around it, the usefulness of a circuit arrangement having a linear voltage/frequency characteristic extends beyond this to such applications as r.f. telemetry, "wobbulators", f.m. broadcast transmissions, and linear f.m. signal generators.

It is convenient in practice if the v.c.o. can be constructed using some form of multivibrator circuit in that this avoids the need for inductors, and, with a regard to the potential use of such a v.c.o. in an f.m. tuner demodulator system with an i.f. of 10.7MHz, it is desirable that the controlled frequency range of the circuit should extend some way above this. In view of the small lead inductances and stray capacitances which are demanded for satisfactory operation of any multivibrator circuit at these frequencies, it is helpful if the device can be constructed using some readily available high frequency linear integrated circuit, and the component arrangement has been chosen with this object in mind.

Circuit development

A number of multivibrator arrangements can be adapted to operate in a voltage controlled mode, but for optimum performance in high frequency applications, the non-saturating emitter-coupled systems are preferable. A suitable configuration for a free running square-wave generator is shown in Fig. 1.

In this the operation of the circuit is to switch the current available from the constant current source backwards and forwards between Tr_x and Tr_y. Resistor R_1 is the collector load of Tr_1. When this transistor is conducting, the voltage drop across R_1 will always be constant and independent of the h.t. voltage supply, provided that this does not alter the output of the constant current source. This arrangement offers a high degree of intrinsic frequency stability and if C_T or R_2 is made variable, the "base" frequency can be altered.

A practical system is shown in Fig. 2, using a Motorola MFC6010 i.f. integrated circuit amplifier, which incorporates a long tailed pair, a constant current source and a reference voltage point. With a stabilised h.t. supply, this circuit gives a high long term frequency stability, and will operate to at least 20MHz.

This circuit arrangement can be converted into a linear and stable voltage controlled oscillator by the substitution of a "current mimic" or "current mirror" circuit for the timing resistor R_2 in Fig. 2.

Current mimic operation

The circuit configuration shown in Fig. 3 is widely used in integrated circuit manufacture, as for example in the Motorola MC3401P to provide a non-inverting input on a Liniac type amplifier, or in the RCA CA3060/3080 micropower op-amps, to replace load resistors. Its attractiveness to the monolithic integrated circuit manufacturer arises from the ease with which identical pairs of transistors can be fabricated in this process.

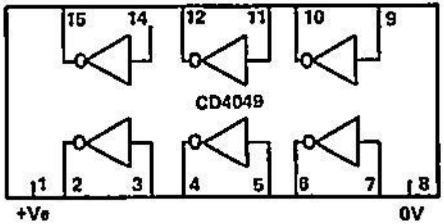
If a given forward bias voltage is applied to the bases of an ideal identical pair of transistors, the same current will flow in the collector circuits of both. If, now, the bases of both of these transistors are joined to the collector of one of these (Tr_a), and a certain current is drawn from this, this current will be the collector current of Tr_a plus the two base currents. Since the forward base potential of Tr_a has adjusted itself to the level required to produce the collector current of Tr_a, it will also have adjusted the base potential of Tr_b to produce the same collector current in Tr_b.

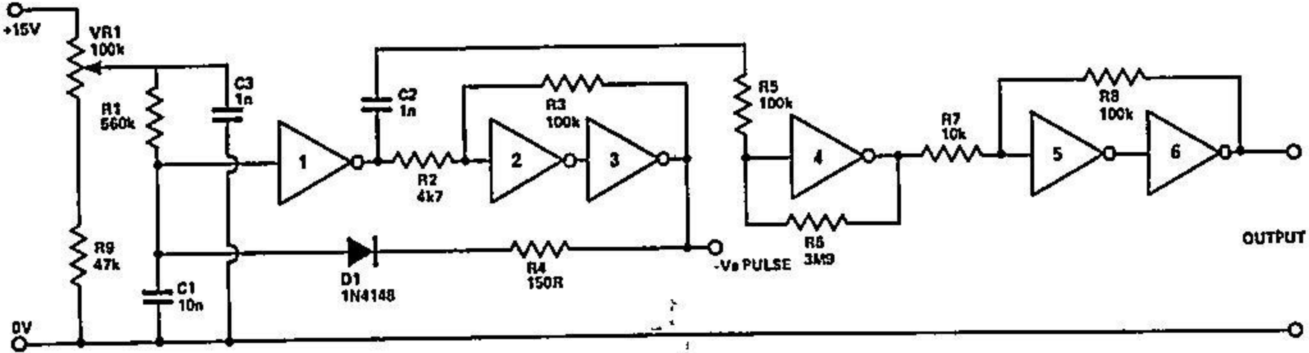
This will imply that the output ("mirror") current of Tr_b will be the same as the current drawn from the input, less the two base current contributions. If the current gains of the transistors used are high enough, or if — as will be the case in integrated circuit manufacture — the

Cheapo VCO

A. J. Richardson

This circuit provides a cheap solution to a non precision voltage controlled oscillator. C1 charges towards the voltage set on VR1 until inverter 1 output goes low whereupon the output of inverter 3 goes low and discharges C1 via D and R4. Inverters 2 and 3 form a Schmitt trigger circuit with positive feedback supplied by R3. Inverter 4 forms a linear amplifier with its gain set by the ratio of R5 to R6 which squares up the signal appearing on inverter 1 output. The signal is further squared up by the Schmitt trigger action of inverters 5 and 6 to provide a square wave of approximately 50% duty cycle at the output of inverter 6. With the values shown a frequency range of at least 100 Hz to 15 kHz is guaranteed with VR1 but other ranges can be covered with suitable values of R1 and C1. The circuit works well at lower supply voltages but the frequency range covered for a given set of components may be slightly less. If a square wave is not required a negative pulse of approximately 200 nS is available at the output of inverter 3 thus enabling two VCOs to be built with one chip.



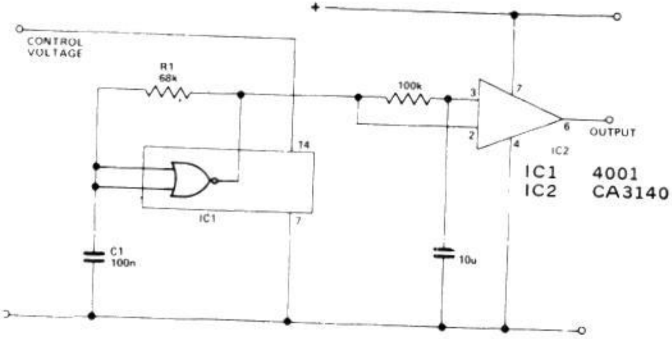


Wide Range Voltage Controlled Oscillator

Any section of IC1 can be used but all unused inputs must be grounded — otherwise the CMOS will pick up line hum and operate in its linear region, overheating as a result.

With the values shown, a frequency range of about 50Hz to 2kHz is obtained — just right for an audio sweep oscillator. If the mark/space ratio is unimportant, it can go down to 1Hz.

The control voltage, which ideally should be in the range 1.5V to 3.5V, is applied to the power supply connections. IC2 is used to square up and buffer the output.



IC1	4001
IC2	CA3140

The ASP strikes again

An ASP should be approached with caution, as H. Harper points out in his letter in the March issue. As it is, the ASP has struck again. Unfortunately Mr Harper gives no details regarding his analysis or the transistors used in his experiments. His results are rather misleading if it is assumed that transistors belonging to the class of popular small-signal audio transistors are used in the circuit. Typical examples are the BC107, BC109, BC169, BC257, etc.

Before I advanced the approximate analysis in my letter in the January issue, an exact analysis of the circuit shown in Fig. 1 was made. Approximations were made only after an experimental investigation. With the equations given, results should be within a 30% margin of error, which is not too far off the mark if all approximations are taken into account. The basic assumption was made that transistors with small values of h_{re} would always be used. I quote the following experimental results, which were obtained from the circuit shown in Fig. 1—essentially the same as the circuit in my previous letter. A BC257A was used for Tr_2, and five different BC169Cs for Tr_1.

Using the approximate formula and manufacturer's data, the limits of the voltage gain using these transistors was calculated as approximately $600 < |A_v| < 2200$.

The following are the measured results with a 1mV r.m.s. input voltage:

1. Voltage gain

frequency: 1000Hz

transistor Tr_1:	a	b	c	d	e
output V r.m.s.	1.45	1.15	1.54	0.90	1.40
voltage gain:	−1450	−1150	−1540	−900	−1400

2. Frequency response

frequency (Hz)	100	1k	10k	80k	100k
output V r.m.s	1.39	1.40	1.40	0.99	0.88
|voltage gain|	1390	1400	1400	990	880

Because Mr Harper furnished few details, I am at a loss to explain why his measured values were so low.

Referring to the case where the collector resistor of the transistor Tr_1 is connected to the 10-volt line, maintaining the same biasing levels and with no resistance in the emitter circuit of Tr_1, the voltage gain of the circuit is given to a good approximation (assuming h_{re1} is small) by

$$A_v = -h_{fe1}R_2/h_{ie1} \approx -g_{m1}R_2 \approx -I_{E1}R_2/25.$$

With the transistor Tr_1 biased at 0.5 mA, this comes to −20, as measured by Mr Harper, and not to −9, as predicted by his computer analysis.

Although the circuit could conceivably go into a state of oscillation when driving a capacitive load, and with the base of Tr_2 capacitively loaded, I have never experienced this in normal applications.

P. W. van der Walt,
University of Stellenbosch,
South Africa.

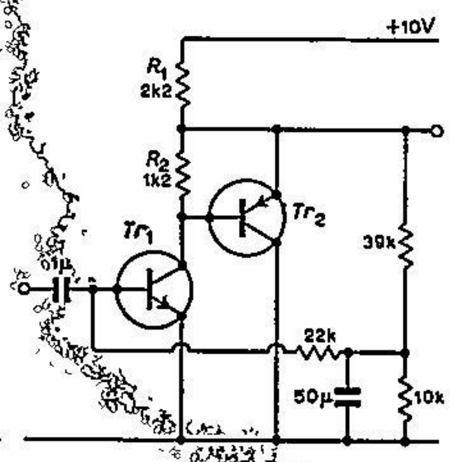
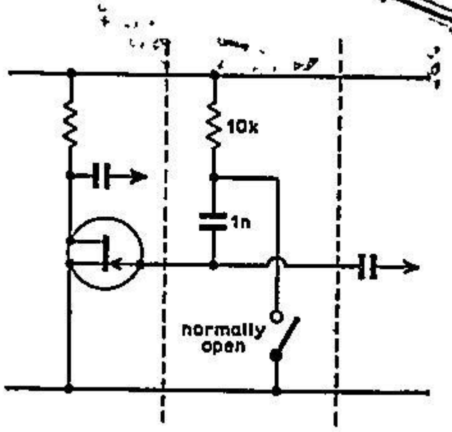


Fig. 1.

Voltage-controlled oscillators

Having a requirement for a voltage-controlled oscillator I constructed a 'lash-up' of circuits 2 and 4 of D. T. Smith's article 'Multivibrators with Seven-decade Range in Period' (February issue). Using 2N5458 (MPF 104) devices for the f.e.ts it was found that the oscillators were not self-starting, but required a negative-going pulse to one of the gates to trigger it. It was further found that if the input voltage was not limited, the circuit would 'latch-up'.

The addition of a resistor, capacitor and switch to one gate circuit, as shown, was found to be sufficient to start and restart the oscillator. The resistor and capacitor alone were sufficient to provide self-starting on switch-on, the switch only being necessary to re-trigger the circuit should the control voltage be allowed to get out of hand. Once started the circuit proved to be quite suitable for the function required of it.



Mr Stiles' addition to Mr D. T. Smith's circuit.

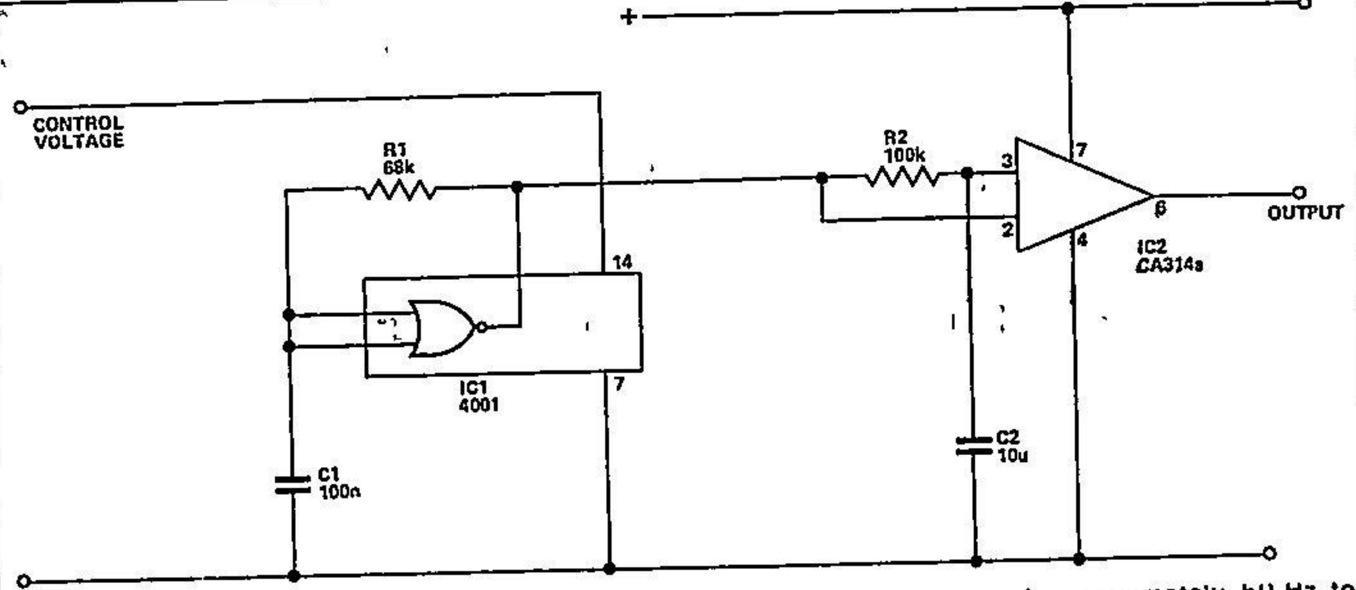
D. B. Stiles,
Bristol,
Somerset.

Automatic telephone exchange

I would like to thank Mr P. F. Gascoyne and Mr N. Monk for their useful comments (April issue) on my design of an automatic telephone exchange (February issue). They have both criticized the power supply section, and I feel I should clarify the situation.

The first point is to assess the merits of using the switched power supply as in my original circuit, or to have a 'permanently on' power supply as suggested by Mr Gascoyne. Both methods have their advantages, and I based my original decision on the expected use of my exchange. Since there were liable to be prolonged periods of inactivity, I felt that a switched power supply would be most suitable. In practice this has worked very well, particularly as the small auxiliary battery lasts over a year. However, if heavy use of the exchange is expected, then perhaps a simpler 'permanently on' power supply would be more appropriate.

Mr Monk is correct to draw attention to the possibility of getting a shock from the mains switching relays. This danger can be avoided by ensuring that the exchange is adequately housed, and that the mains is switched off while it is being handled. Alternatively the contacts could be shielded by commercially available dust covers. More important is the possibility of mains contacts shorting with low-voltage ones. This is indeed possible if they are both wired into the same springset. However, the type 3000 relay has two sets of spring contacts side by side separated by a porcelain insulator; by using one set for mains only and the other set for low-voltage, the danger is overcome.



Simple Wide Range VCO

A J Richardson

Any section of IC1 can be used but all unused inputs must be taken to ground

This circuit takes advantage of the fact that CMOS gates readily oscillate in the circuit configuration shown. The control voltage, which ideally is in the range 1V5 to 3V5, is applied to the power supply connection of IC1. IC2 is used to square up and buffer the output of IC1 and can be operated from any suitable voltage rail

With the values shown a frequency range of approximately 50 Hz to 20 kHz is obtained with almost equal mark to space ratio, but if this is unimportant the lower end can be extended down to approximately 1 Hz Other frequency ranges can be obtained with suitable values of R1 and C1.

Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot answer queries on these items.

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Engineer's newsletter

Chip streamlines audio VCOs

Whether as a home-computer audio output or in an electronic music system, a voltage-controlled oscillator with an exponential output is useful for making a variety of sounds. Numerous ways of building the device have been proposed, one of the latest having come from Jim Williams [*Electronics*, July 28, p. 136]. But it turns out an integrated circuit is available that does the job of Williams's oscillator with far fewer parts, at less expense—and without a heater.

According to Douglas R. Curtis of Curtis Electromusic Specialties Inc., the CEM3340 is a voltage-controlled oscillator that can be swept over a frequency range with a ratio of 50,000:1 minimum, producing either an exponential or a linear output. The IC is also fully temperature-compensated. For further information, write to Curtis at 110 Highland Ave., Los Gatos, Calif. 95030, or call him at (408) 395-3350.

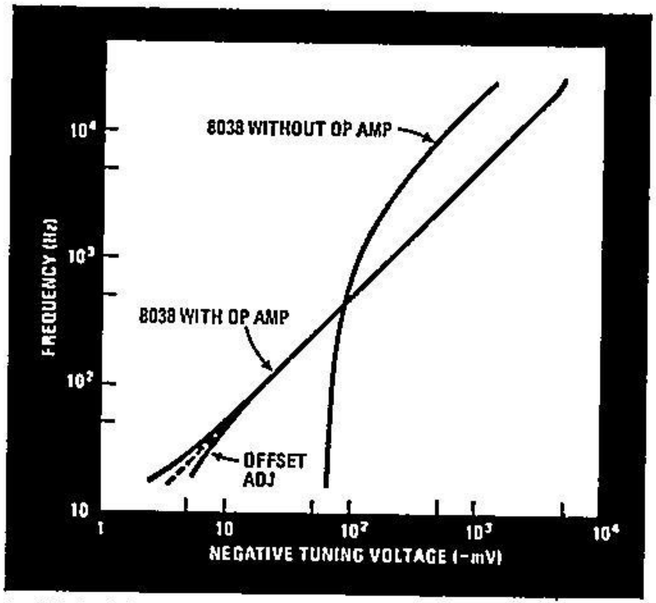
Modified function generator yields linear VCO

by Antonio Tagliavini
Bologna, Italy

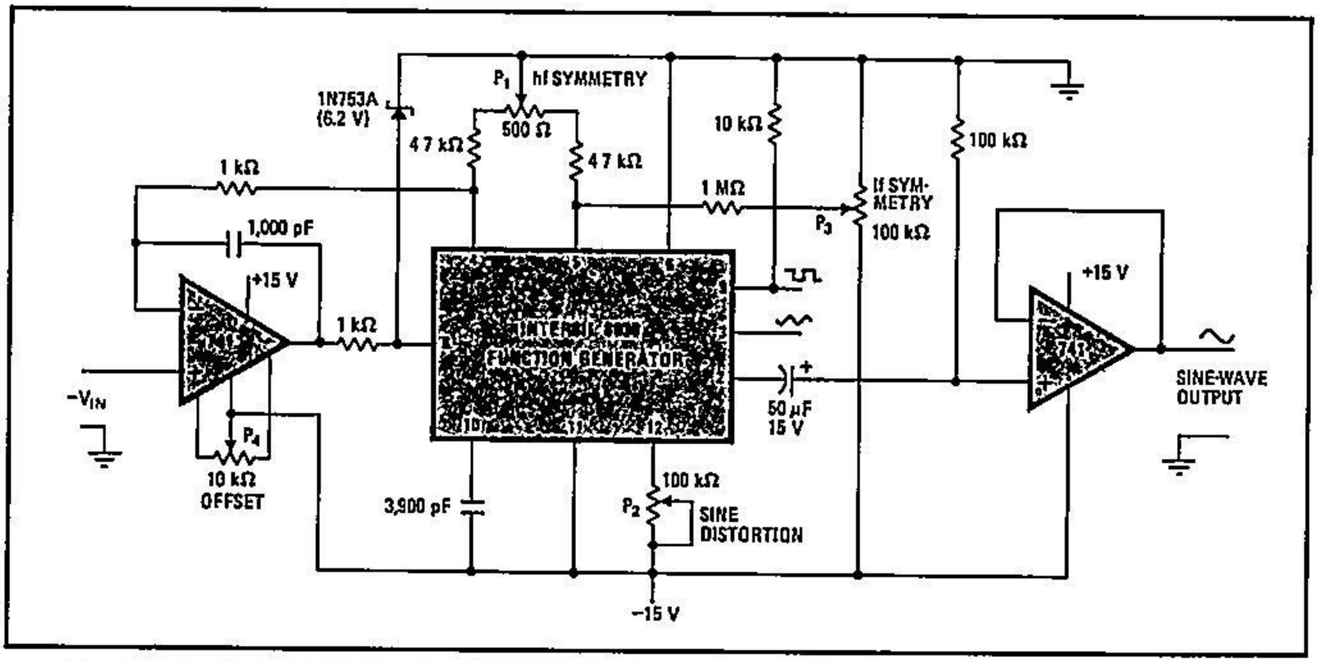
Because of its wide sweep capability, the Intersil 8038 integrated function generator is useful for realizing a voltage-controlled oscillator with a sine-wave output. But because of the limitations of the 8038's integrated current sources, its frequency-versus-voltage characteristic is nonlinear over a good part of its sweep range. As Fig. 1 shows, however, the tuning can be made linear over the entire audio range if an external operational amplifier is added before the function generator's control input.

The 8038 contains two current sources. One is always operating, supplying an external integrating capacitor with a constant current I. The other is switched on and off by a level comparator, supplying the capacitor with a current –2I when on. Therefore the capacitor is charged by I and discharged by –I, producing a symmetrical triangular wave (which is then converted into a sine wave) with a frequency that is proportional to current I. This current does not vary linearly with the input voltage, and therefore the relationship between input voltage and frequency is not linear.

To linearize the relationship, the timing voltage is applied to the control input terminal of the 8038 (pin 8) through an operational amplifier, as shown in Fig. 2. The op amp drives the integrated non-switched current source, and because the voltage fed back to the inverting input terminal of the op amp must equal V_{in}, the



1. All straightened out. Voltage/frequency characteristic of the Intersil 8038 voltage-controlled audio-frequency oscillator is not linear But if the input voltage is applied to the 8038 through an operational amplifier, with feedback through one of the integrated current sources on the IC chip, the tuning curve becomes a straight line



2. Line straightener. Linear VCO circuit uses 741 op-amp input to linearize one of the two current sources in the 8038 function generator. Because the two sources are inherently matched, the second source tracks the first and also gives linear current-to-voltage response. Output op-amp buffer provides low output impedance Pots shape sinusoidal output wave form and maintain linearity at low frequencies.

current supplied by this source varies directly with V_{in}. The two integrated current generators in the 8038 are inherently matched, so the switched source tracks the non-switched one and therefore is also linearized. The switched source drives a current inverter/doubler that provides the current −2I.

The 1N753A zener diode protects the control input of the function generator IC against voltages more positive than +0.6 volt and more negative than −6.2 V. The output operational amplifier is merely a buffer, and may be omitted if low output impedance is not required.

Three potentiometers permit shaping of the output waveform. First, at a high frequency, P_1 is adjusted to obtain a symmetrical wave shape (square wave from pin 9). Then P_2 is set for best sinusoidal output. Finally P_3 is trimmed for good symmetry at the low-frequency end of the tuning curve. The offset adjustment, P_4, is then adjusted to provide tuning linearity.

With component values shown, the VCO covers the entire audio range (20 to 20,000 hertz). ☐

Antilog function generator keeps VCO output linear

by J. A Connelly and C. D Thompson
Georgia Institute of Technology, Atlanta, Ga

Accurate voltage control of oscillator frequency is crucial for such applications as electronic music synthesizers, filter test circuits, and phase-locked loops. In the voltage-controlled oscillator (VCO) described here, each 1-volt change in the control voltage changes the output frequency by one octave with a maximum deviation of ±0.4% over the entire audio range. This precision is achieved by temperature-compensation and buffering.

Circuit can be built with readily available parts, and the design equations allow adjustability and flexibility to meet a variety of specific needs. The total range of oscillation frequency can be shifted down one octave, for example, by doubling the capacitance of C_1 in the VCO.

This VCO is basically a relaxation oscillator: current source Q_5 charges low-leakage polystyrene capacitor C_1 until unijunction transistor Q_4 fires (at about 9 V); C_1 then discharges rapidly, and the cycle starts all over again. The sawtooth output voltage essentially results from the voltage across C_1 minus a couple of junction voltages, buffered by high-impedance MOSFET Q_2; by Q_3, which carries the current to fire Q_4; and by the unity-gain op amp. Most of the resistors limit transistor currents to safe levels.

The oscillation frequency is determined by the charging current into C_1. This current, which is the collector current from Q_{5B}, depends upon the control voltage because the base-to-emitter voltage V_{BE} in both halves of Q_5 is derived from the control voltage, thus,

$$I_C = \beta I_S \exp(qV_{BE}/kT)$$

where β is the short-circuit current gain, I_S is the reverse saturation current, kT/q is 0.026 per volt at 27°C, and V_{BE} is scaled from the control voltage V in a voltage-divider network:

$$V_{BE} = VR_{TC}/(R_{IN} + R_{TC})$$

Therefore, the collector current is given as a function of the control voltage by

$$I_C = \beta I_S \exp\left[\frac{qR_{TC}V}{kT(R_{IN} + R_{TC})}\right] = \beta I_S K^V$$

In this expression, the scale factor K is just a substitution that replaces several terms: that is,

$$K = \exp\left[\frac{qR_{TC}}{kT(R_{IN} + R_{TC})}\right]$$

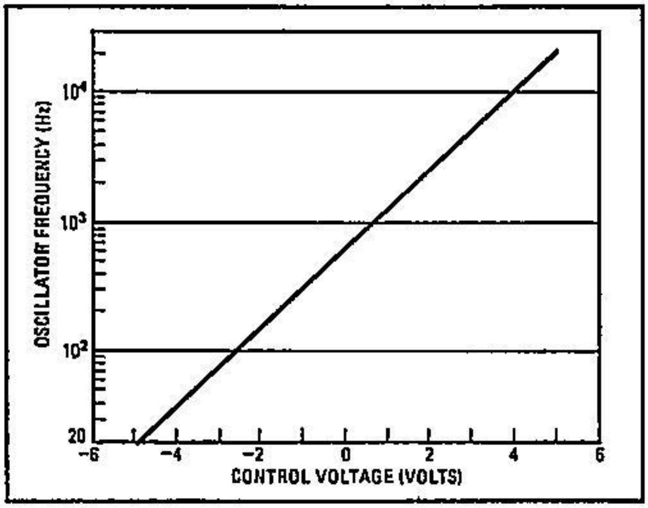
Current I_C is an antilog function (or exponential function) of voltage, and therefore the current source is called an antilog function generator.

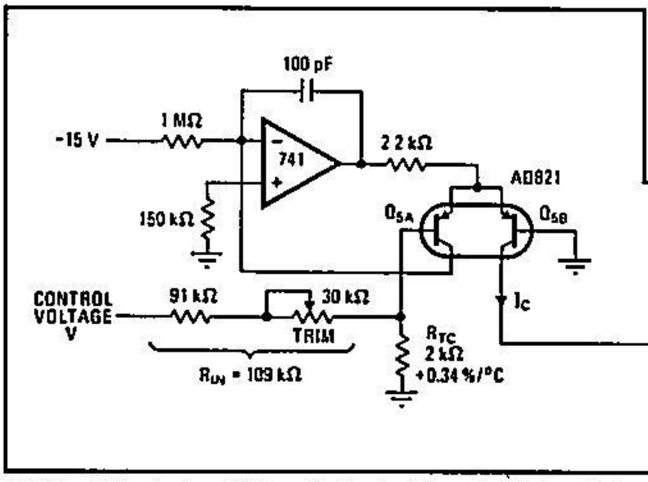
Because the frequency is directly proportional to I_C,

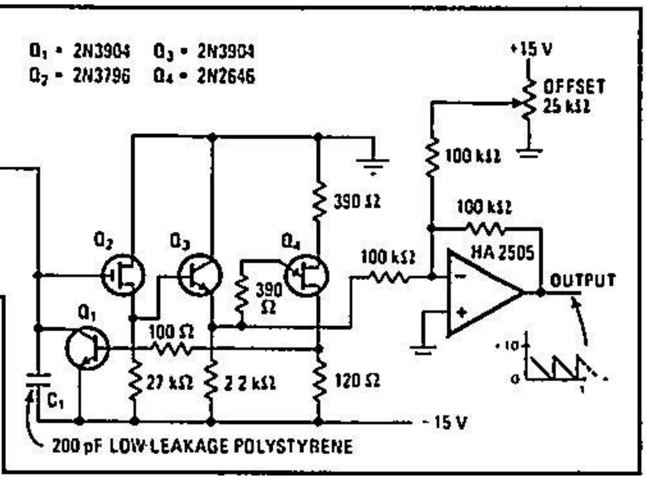
$$f \sim K^V = f_0 K^V$$

where f_0 is the free-running frequency (i.e., the oscillator frequency when control voltage V is zero). The frequency f_0 depends on the parameters of Q_5, the firing voltage of Q_4, and the capacitance of C_1.

The value of scale factor K is set by the resistors R_{IN}







Voltage-controlled oscillator. Basic circuit is relaxation oscillator built around timing capacitor C_1 and unijunction transistor Antilog function generator (in shaded area) supplies charging current that varies exponentially with control voltage Tuning curve is 1-octave-per-volt straight line If R_{IN} were 31 4 kilohms, tuning curve would be one-decade-per-volt straight line and R_{TC} in the divider network. If K is 10, the oscillation frequency changes by one decade when V changes by 1 v With the resistance values shown in the circuit diagram, however, K is 2, so the frequency changes by one octave when V changes by 1 v

The temperature sensitivity of I_C is compensated by the temperature coefficient of thermistor R_{TC}, +0.34%/°C, which is equal in magnitude and opposite in sign to the effect of q/kT in the expression for K. Thus, scale factor K is independent of temperature if the thermistor and Q_5 have equal temperatures. To ensure this condition, the thermistor is mounted in thermal contact with the header of Q_5.

The tuning curve shows the experimental performance of the VCO The maximum departure from the straight-line relationship is only ±0.4% over the audio-frequency range from 20 Hz to 20 kHz. Outside that range, the voltage control becomes less precise. ☐

Radiation monitor has linear output

by Paul Prazak, *Burr-Brown Research Corp Tucson, Ariz*
and Lt William B Scott, *Edwards AFB Calif*

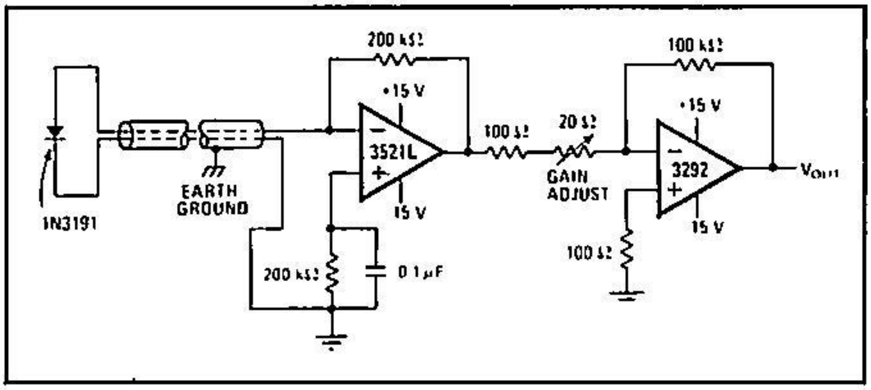
A commercial silicon diode can be used as a direct-reading detector of gamma rays and high-energy X rays in radiotherapy. Besides generating an output that is linearly proportional to the radiation intensity, the diode makes a small enough probe to map the radiation field accurately. The monitoring system of diode plus two operational amplifiers provides an output voltage that varies linearly from 0.1 volt to 10 V as the dose rate varies from 10 rads per minute to 1,000 rads/min.

The 1N3191 or other off-the-shelf diode is operated in a zero-bias short-circuit mode. Irradiation of the diode junction creates electrons and holes that are collected by the depletion gradient, producing a nanoampere current which is proportional to the intensity of the radiation.

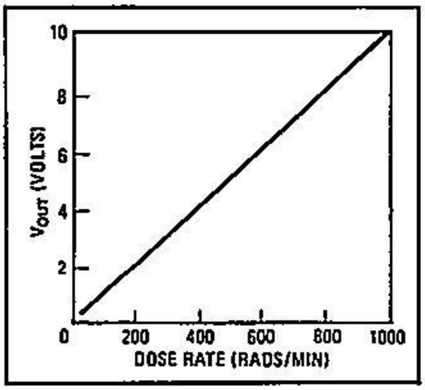
To amplify the small signal from the diode, a 3521L operational amplifier with low bias current (10 picoamperes maximum) and ultra-low offset voltage drift (±1 microvolt/°C maximum) is used. As shown in Fig 1, the 3521L is connected in a current-to-voltage configuration where the inverting input appears as a virtual ground This FET-input op amp delivers output voltages of 100 μV to 10 millivolts, which are well above the noise level. The 200-kilohm resistor between ground and the noninverting input serves to balance the amplifier, and the 0 1-microfarad capacitor stabilizes the amplifier by shunting out noise and preventing oscillations resulting from positive feedback

An additional stage of gain amplifies the signal to the desired level. The offset-voltage drift of this stage must be extremely low because it is amplified along with the signal Therefore the chopper-stabilized 3292 op amp, which has a maximum offset drift of only ±0.3 μV/°C is used here. The 100-ohm resistor again balances the inputs to the amplifier. The gain of this stage should be around 1,000, it is adjusted by means of the 20-ohm potentiometer so that an output voltage of 0.10 V to 10.00 V corresponds to a dose rate of 10 rads/min to 1,000 rads/min at the detector, as shown in Fig. 2.

The output voltage can be displayed on a 3½-digit panel meter, so that the numerals directly indicate radiation intensity An alternative is to use an ultralinear voltage-to-frequency converter, an optical coupler, a counter, and a display to completely isolate the radiotherapy patient from the monitoring and recording system An advantage of this approach is that the integrating input of the voltage/frequency converter would average out any high-frequency noise in the system. ☐



1. Dosage-rate meter. Commercial diode is detector in this highly accurate radiation monitor Low-drift FET-input op amp amplifies detector current to usable level, and chopper-stabilized amplifier then provides additional gain while minimizing any error caused by ambient-temperature fluctuations Gain is adjusted so that output voltage is 1% of incident radiation intensity in rads per minute, therefore voltage can be displayed on 3½-digit DVM for direct reading of dosage rate Cost of parts for this monitor is about $90



2. Linear response. Output voltage from monitor is linearly proportional to radiation intensity at diode Over dosage rate range shown, total system error is less than 1% Small size of diode probe permits accurate mapping of radiation field

Two-chip VCO linearly controls ramp's amplitude and frequency

by Forrest P. Clay Jr and Mark S Eaton
Department of Physics, Old Dominion University, Norfolk, Va.

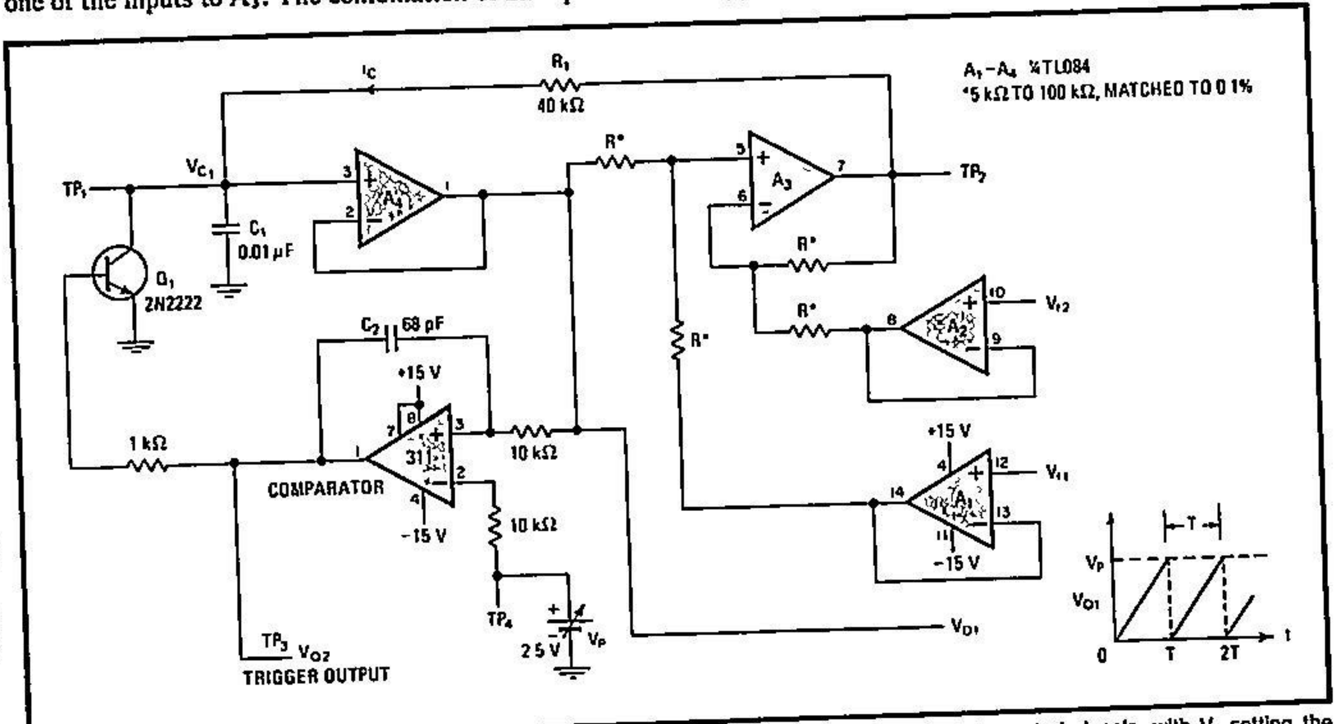
This inexpensive ramp generator provides a proportional voltage control of both the period and amplitude of a waveform over a wide range and thus doubles as a linear voltage-to-frequency converter. Only a few active devices are needed: two operational amplifiers and a transistor.

Two dc differential control signals, V_{f_1} and V_{f_2}, are applied to op amps A_1 and A_2. The output from A_3 is $V_{C_1}+(V_{f_1}-V_{f_2}) = V_{C_1}+V_f$, where V_{C_1} is the voltage across ramp capacitor C_1 and after buffering becomes one of the inputs to A_3. The combination of all inputs to A_3 yields a dc bootstrap circuit with a controlled offset voltage. Thus, current $i_c = (V_{C_1}+V_f-V_{C_1})/R_1 = V_f/R_1$, and the voltage across the capacitor is

$$V_{C_1} = \int_0^t (i_c/C_1)dt = (V_f/R_1C_1)t$$

C_1 is discharged through transistor Q_1 at time T when V_{C_1} equals the control voltage V_p, which is adjustable from 0 to 2.5 volts. thus $[V_{C_1}]_{max} = V_p = (V_f/R_1C_1)\,T$ and $f = 1/T = V_f/V_pR_1C_1$. The 311 comparator has a trigger output to synchronize external circuitry for easy operation.

The slope of the control voltage versus frequency in kilohertz is 1 for $1<V_f<10$ volts. This linear relationship holds even for slow ramps (increasing the value of C_1) with small values of V_f. Capacitor C_2 is selected to maintain the 311's output in a high state long enough so that C_1 may be completely discharged through Q_1 during the appropriate portion of the cycle. ☐



Potentially proportioned. A two-chip, one-transistor ramp generator is linearly adjusted by two dc control signals, with V_p setting the amplitude from 0 to 2.5 volts and V_f and V_o setting the frequency over the range of 0 to 10 kilohertz. Proportional control is achieved by placing ramp capacitor C_1 in the dc bootstrap circuit of A_3 and A_4, which ensures that constant current I_c is a function of only V_f and R_1.

STATE OF SOLID STATE

VCO

ROBERT F. SCOTT,
SEMICONDUCTOR EDITOR

Micropower op-amp

PRECISION MONOLITHICS, INC. CLAIMS that their new OP-90 micropower op-amp sets new performance standards for similar devices. Although the OP-90's performance is comparable to that of the OP-07, it draws less than 20 μA—which is 1/200,000 the current needed for the OP-07. The OP-90's gain exceeds 700,000 (700V/mV), and common mode rejection is better than 100 dB.

In addition to its unusually low current drain, the op-amp can operate from a single-ended (single) power supply of +1.6 to +36 volts, or from a bipolar (dual) supply of ±0.8 to ±18 volts. As a single-source device, both input and output are referenced to ground and "zero-in/zero-out" (no static DC output) operation is possible. Input offset is less than 150 μV, so external nulling is not required in most applications.

The OP-90's low offset voltage and high gain enables it to provide precision performance in low-frequency micropower applications. Its exceptionally low voltage and current requirements make the device ideal for battery and solar-power operation in such applications as portable instruments, remote sensors, and satellites.

The OP-90 has the same pinout as the 741, has nulling to V−, and can be used to upgrade low-frequency equipment that presently uses the OP-20, ICL8021, HA5141, LF441, or the OPA21. It is available as the OP-90GP in an 8-pin plastic DIP with a commercial temperature range (At T_A = 25°C, maximum offset voltage is 450 μV.) It is also available as the OP-90AZ and OP-90EZ; those are hermetic 8-pin DIP's with the former operating in the military temperature range and the latter in the industrial range. Both have $V_{OS(max)}$ of 150 μV at 25°C available. Another version, the OP-90FZ, also in a hermetic DIP; that device operates in the industrial temperature range and has 250-μV maximum voltage offset.

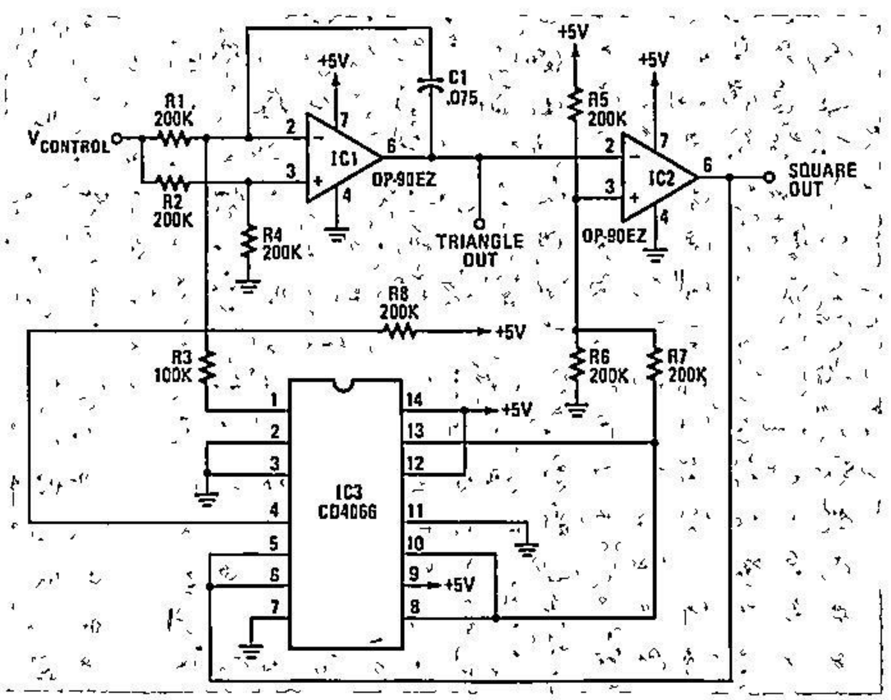


FIG. 1

Figure 1 shows how two OP-90's and a CD4066 CMOS quad bilateral switch can be used to make an inexpensive precision voltage-controlled oscillator. The oscillator provides squarewave and trianglular-wave outputs up to a few hundred hertz, and draws only 50 μA from a 5-volt power supply.

Op-amp IC1 is connected as an integrator. Op-amp IC2 is used as a Schmitt trigger, with resistors R5, R6, R7 and the associated internal CMOS switches setting the hysteresis to precisely 1.67 volts. The Schmitt-trigger action shapes IC1's output into a trianglular waveform of 3.33 volts peak (5.00V − 1.67V). IC2's output is a squarewave whose amplitude swing is essentially zero to +5 volts.

The output frequency for the oscillator shown in Fig. 1 is:

$$f_{out} = V_{in(volts)} \times 10Hz/V$$

however, frequency can be varied—within limits—by changing the value of integrating capacitor C1. R-E

Two-phase v.c.o.

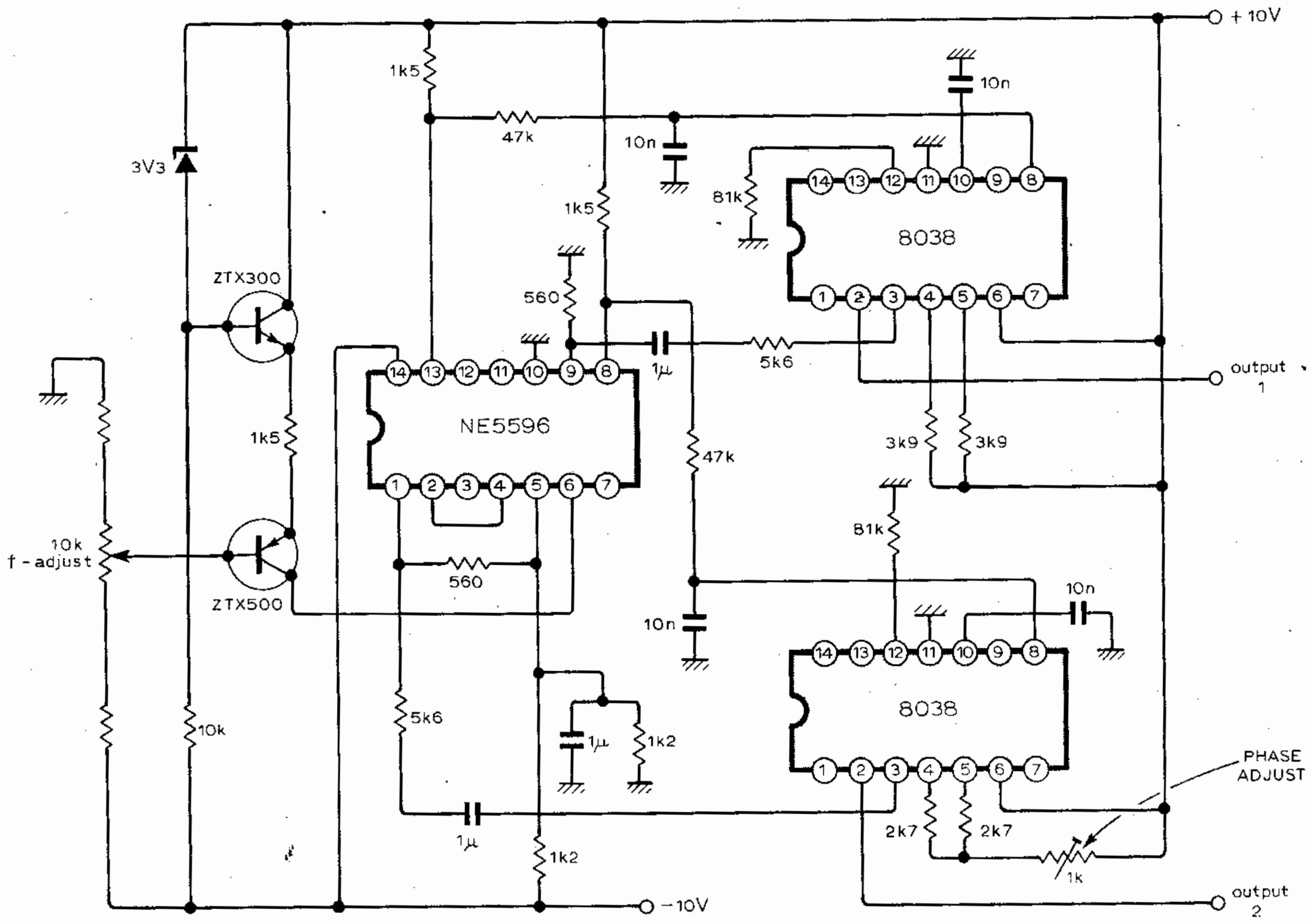
The standard method of obtaining an oscillator that will deliver a two-phase output (i.e. sin and cos) is to follow a conventional oscillator by a phase-locked loop, thus generating the quadrature signal. This has the disadvantage that, if a variable frequency is required, the capture range of the p.l.l. may be exceeded, or there could be a large phase error.

This oscillator is based on the above approach, but is a symmetrical version which does not have a restricted range or phase error. The circuit consists of two v.c.os, and pin connections are shown for the 8038 which gives a sinusoidal output. The i.cs are driven from a standard NE5596 multiplier circuit via a low pass filter. The two oscillators are locked together in frequency and 90° apart in phase by taking their triangular outputs to the multiplier inputs. A 90° phase difference between them causes equal d.c. collector voltages, and any deviation from 90° produces a voltage difference across the collectors which restores the phase.

Frequency of the oscillators is varied by producing a common-mode output voltage in the multiplier. This is achieved by altering the bias current. Thus, the oscillator is tuneable over a wide range, with nominally zero phase error.

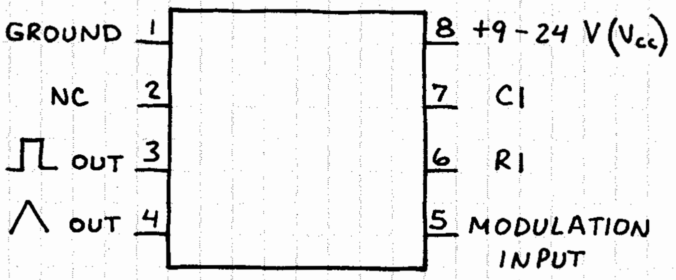
The frequency adjust potentiometer and resistors are set to give the required range, but the potentiometer can be eliminated if v.c.o. operation is required. If sinusoidal outputs are not needed the cheaper 566 type of v.c.o. can be used.

J. M. Worley,
Colchester,
Essex.



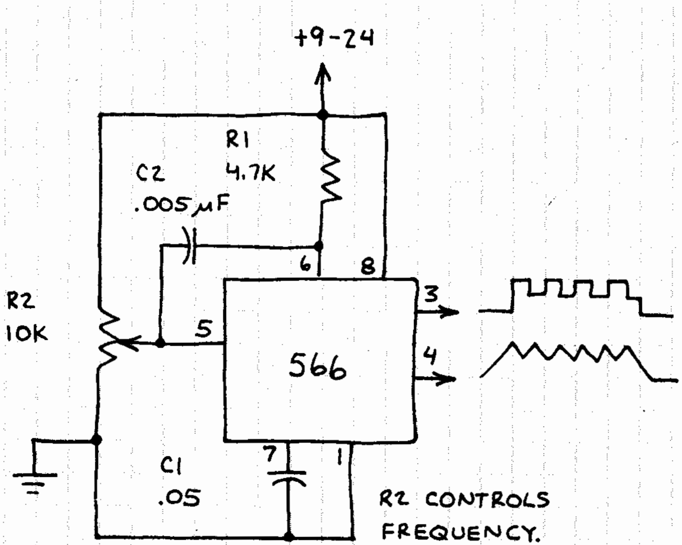
VOLTAGE CONTROLLED OSCILLATOR (VCO) 566

VERY STABLE, EASY TO USE TRIANGLE AND SQUARE WAVE OUTPUTS. R1 AND C1 CONTROL CENTER FREQUENCY. VOLTAGE AT PIN 5 VARIES FREQUENCY. IMPORTANT: OUTPUT WAVE DOES NOT FALL TO 0 VOLT! AT 12 VOLTS (PIN 8), FOR EXAMPLE, TRIANGLE OUTPUT CYCLES BETWEEN +4 AND +6 VOLTS. SQUARE OUTPUT CYCLES BETWEEN +6 AND +11.5 VOLTS.



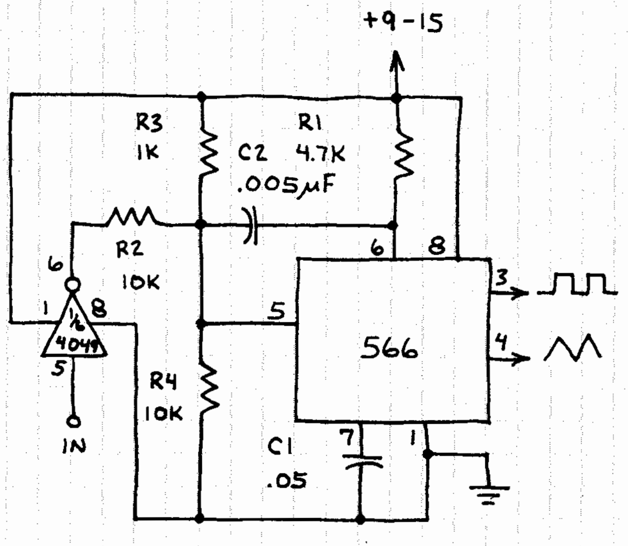
$$\text{CENTER FREQUENCY} = \frac{2\,(V_{cc} - \text{INPUT VOLTS})}{R1\ C1\ V_{cc}}$$

FUNCTION GENERATOR



R2 CONTROLS FREQUENCY.

FSK GENERATOR*



* FSK MEANS FREQUENCY SHIFT KEYING.

IN	OUTPUT
L	1.5 KHz
H	3.0 KHz

USE TO TRANSMIT BINARY DATA OVER TELEPHONE LINES OR STORE BINARY DATA ON MAGNETIC TAPE.

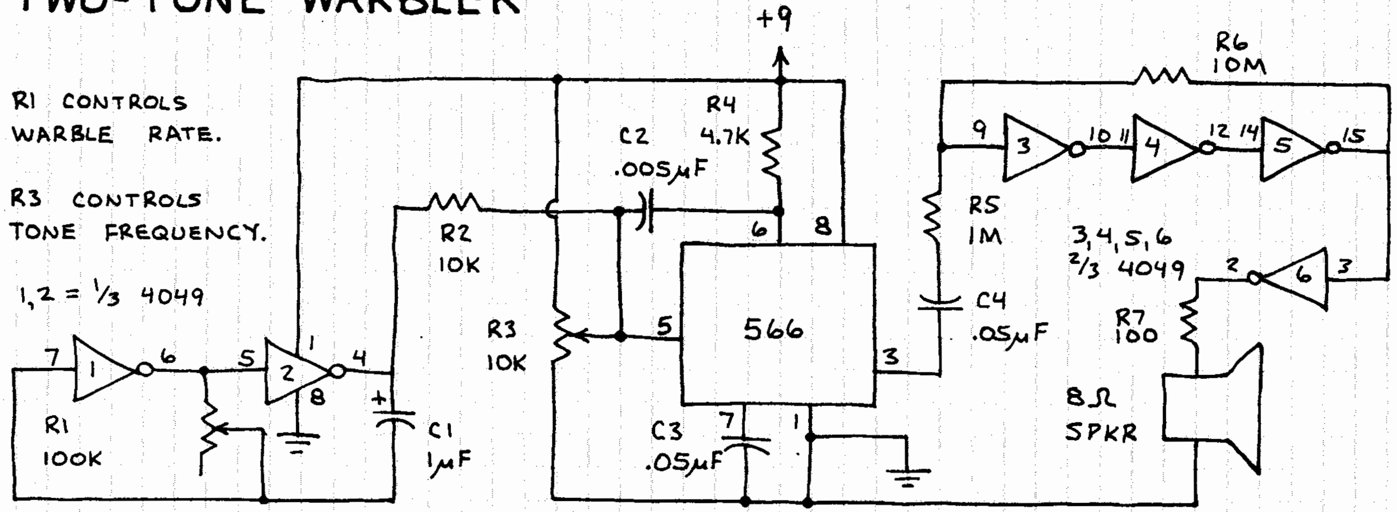
V_{cc} = 9 VOLTS.

TWO-TONE WARBLER

R1 CONTROLS WARBLE RATE.

R3 CONTROLS TONE FREQUENCY.

1,2 = 1/3 4049



A SIMPLE V.C.O.

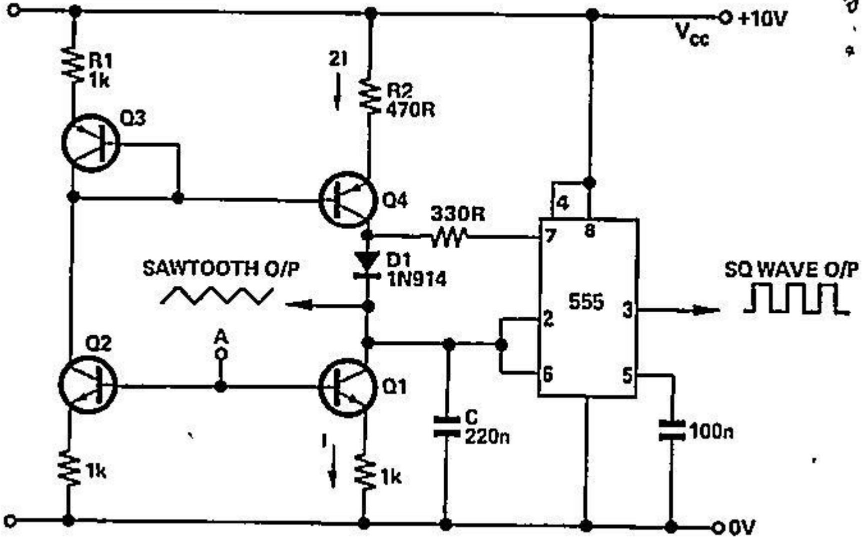
This circuit generates sawtooth and triangle waveforms at a frequency set by an external control voltage.

Current source Q1 draws a current I from timing capacitor C. Simultaneously current source Q2 draws the same current from current mirror Q3, Q4; this is set up (by R1 and R2) to deliver (from the collector of Q4) twice the current leaving Q2.

Hence C receives a current 2 I from the top rail, at the same time delivering I to the bottom rail, the net effect being that the capacitor is charged by a constant current I, its voltage rising linearly until the 555's upper trigger point (at 2/3Vcc) is reached.

The output (pin 3) then goes low, as does the open-collector discharge output at pin 7. The latter shunts the output of the current mirror to earth, D1 becoming reverse-biased and isolating C.

Now only current source Q1 is connected to the timing capacitor which is now linearly discharged by current I. In this way C is alternately charged and discharged. When the voltage on C falls to the 555's lower trigger point at 1/3Vcc, the output and discharge pins go high, and the cycle recommences; the repetition frequency is determined by the magnitude of I, which is set by the voltage applied at the input point A.



With the component values shown, the frequency range is from approx. 2.5 kHz to less than 10 Hz, as the control voltage varies from +10 V to zero; the frequency is directly proportional to the control voltage. Other ranges may be obtained by altering the value of C

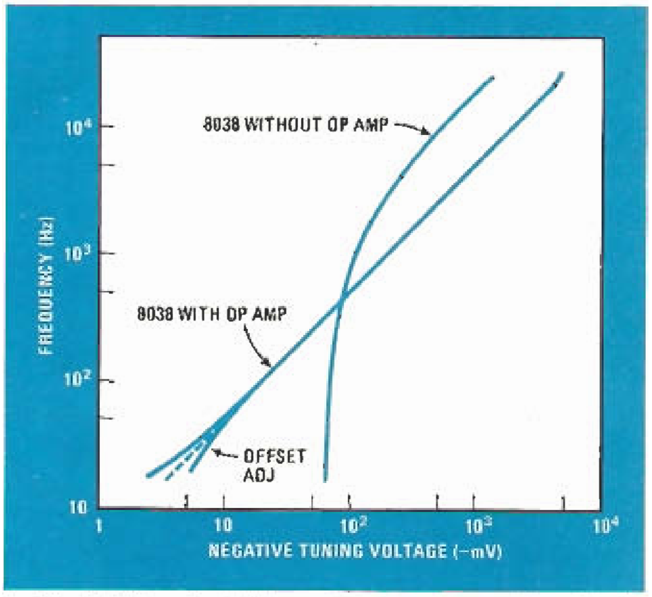
Modified function generator yields linear VCO

by Antonio Tagliavini
Bologna, Italy

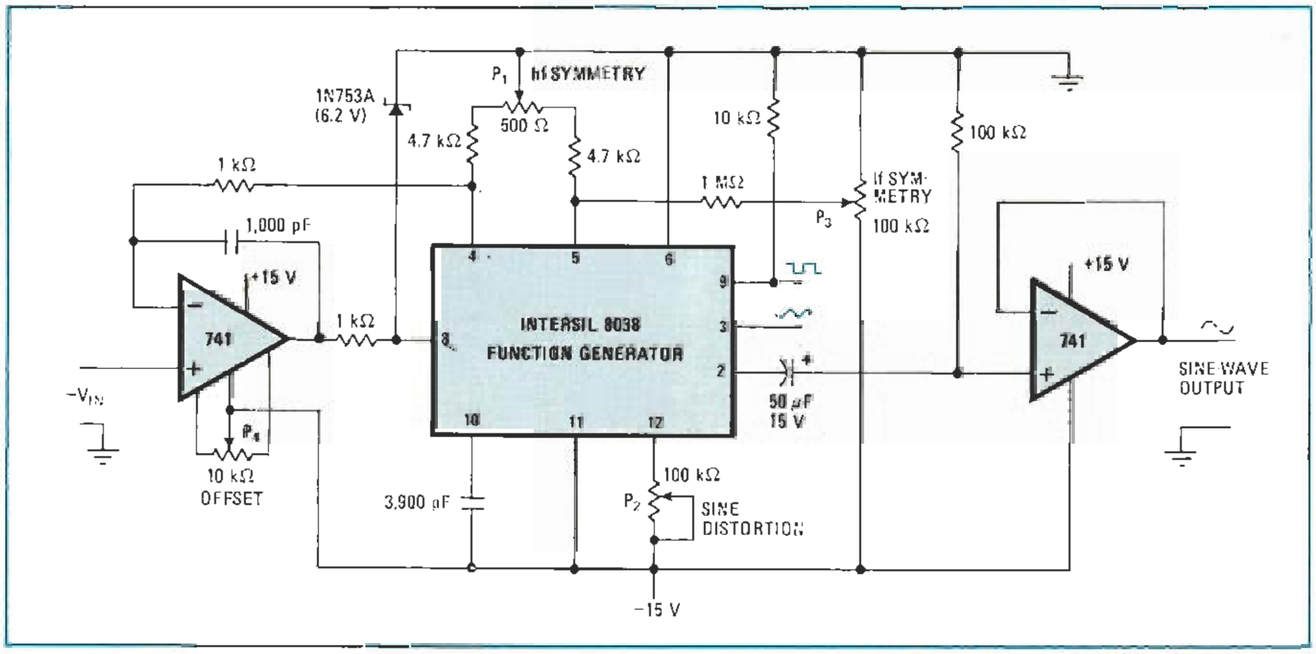
Because of its wide sweep capability, the Intersil 8038 integrated function generator is useful for realizing a voltage-controlled oscillator with a sine-wave output. But because of the limitations of the 8038's integrated current sources, its frequency-versus-voltage characteristic is nonlinear over a good part of its sweep range. As Fig. 1 shows, however, the tuning can be made linear over the entire audio range if an external operational amplifier is added before the function generator's control input.

The 8038 contains two current sources. One is always operating, supplying an external integrating capacitor with a constant current I. The other is switched on and off by a level comparator, supplying the capacitor with a current −2I when on. Therefore the capacitor is charged by I and discharged by −I, producing a symmetrical triangular wave (which is then converted into a sine wave) with a frequency that is proportional to current I. This current does not vary linearly with the input voltage, and therefore the relationship between input voltage and frequency is not linear.

To linearize the relationship, the timing voltage is applied to the control input terminal of the 8038 (pin 8) through an operational amplifier, as shown in Fig. 2. The op amp drives the integrated non-switched current source, and because the voltage fed back to the inverting input terminal of the op amp must equal V_{in}, the



1. All straightened out. Voltage/frequency characteristic of the Intersil 8038 voltage-controlled audio-frequency oscillator is not linear. But if the input voltage is applied to the 8038 through an operational amplifier, with feedback through one of the integrated current sources on the IC chip, the tuning curve becomes a straight line.



2. Line straightener. Linear VCO circuit uses 741 op-amp input to linearize one of the two current sources in the 8038 function generator. Because the two sources are inherently matched, the second source tracks the first and also gives linear current-to-voltage response. Output op-amp buffer provides low output impedance. Pots shape sinusoidal output wave form and maintain linearity at low frequencies.

current supplied by this source varies directly with V_{in}. The two integrated current generators in the 8038 are inherently matched, so the switched source tracks the non-switched one and therefore is also linearized. The switched source drives a current inverter/doubler that provides the current $-2I$.

The 1N753A zener diode protects the control input of the function generator IC against voltages more positive than +0.6 volt and more negative than -6.2 V. The output operational amplifier is merely a buffer, and may be omitted if low output impedance is not required.

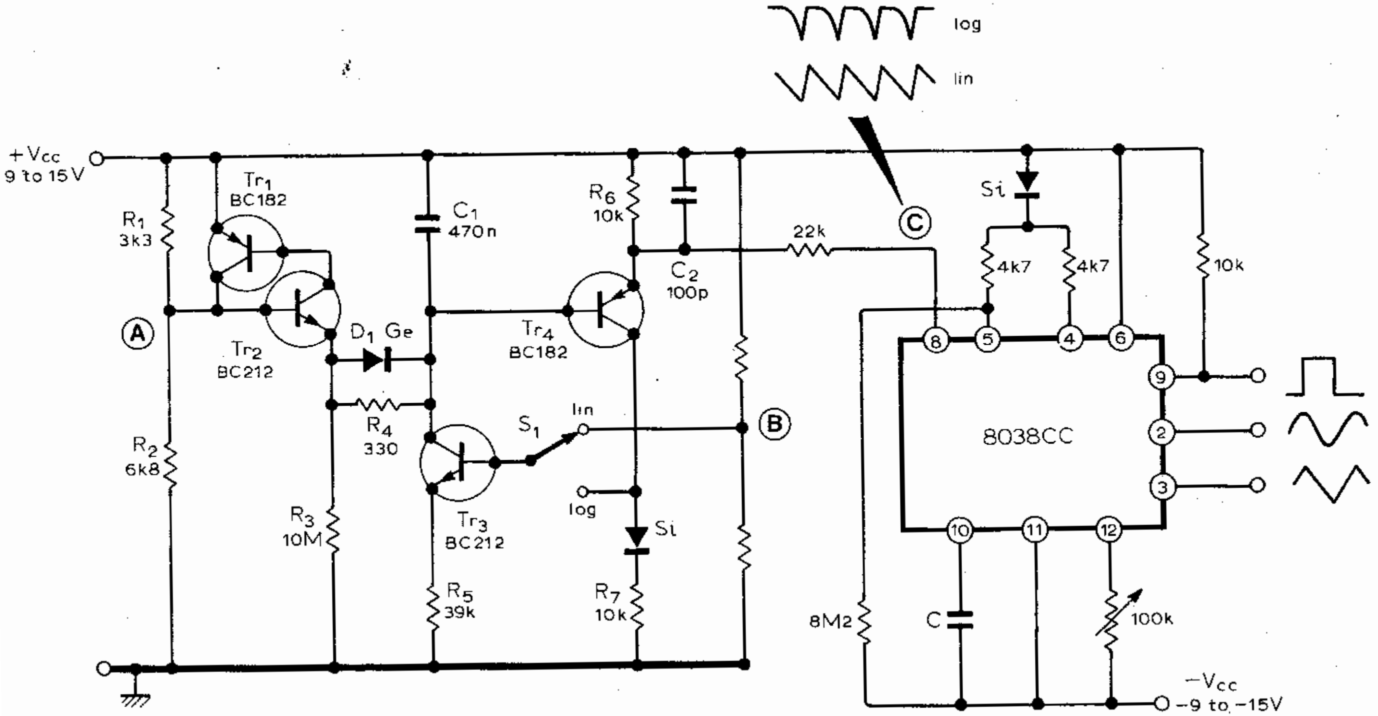
Three potentiometers permit shaping of the output waveform. First, at a high frequency, P_1 is adjusted to obtain a symmetrical wave shape (square wave from pin 9). Then P_2 is set for best sinusoidal output. Finally P_3 is trimmed for good symmetry at the low-frequency end of the tuning curve. The offset adjustment, P_4, is then adjusted to provide tuning linearity.

With component values shown, the VCO covers the entire audio range (20 to 20,000 hertz). □

Linear/logarithmic sweep generator

This circuit provides a logarithmic or linear sweep facility for the Intersil 8038 function generator i.c. In the linear mode Tr_3 acts as a constant current generator which charges C_1 almost linearly. Transistors Tr_1 and Tr_2 reset the capacitor as the voltage across it reached about $1/3V_{cc}$ +0.9V. In the logarithmic mode, positive feedback allows exponential charging of the capacitor. Capacitor C_2 shunts the narrow spikes that may occur from the circuit, and R_3 sinks a low starting current without affecting the sweep characteristic. D_1 improves the stability of frequency versus temperature but can be omitted with R_4 to extend the range of the output waveform. Point A has a short positive pulse which may be processed to reset the 8038 capacitor, and to sync an oscilloscope. Voltage at point B must be set experimentally, and is dependent on V_{cc}. An overall frequency control may be achieved by making R_5 variable.

Sergio Villone,
Turin,
Italy.



Antilog function generator keeps VCO output linear

by J. A. Connelly and C. D. Thompson
Georgia Institute of Technology, Atlanta, Ga.

Accurate voltage control of oscillator frequency is crucial for such applications as electronic music synthesizers, filter test circuits, and phase-locked loops. In the voltage-controlled oscillator (VCO) described here, each 1-volt change in the control voltage changes the output frequency by one octave with a maximum deviation of ±0.4% over the entire audio range. This precision is achieved by temperature-compensation and buffering.

Circuit can be built with readily available parts, and the design equations allow adjustability and flexibility to meet a variety of specific needs. The total range of oscillation frequency can be shifted down one octave, for example, by doubling the capacitance of C_1 in the VCO.

This VCO is basically a relaxation oscillator: current source Q_5 charges low-leakage polystyrene capacitor C_1 until unijunction transistor Q_4 fires (at about 9 V); C_1 then discharges rapidly, and the cycle starts all over again. The sawtooth output voltage essentially results from the voltage across C_1 minus a couple of junction voltages, buffered by high-impedance MOSFET Q_2; by Q_3, which carries the current to fire Q_4; and by the unity-gain op amp. Most of the resistors limit transistor currents to safe levels.

The oscillation frequency is determined by the charging current into C_1. This current, which is the collector current from Q_{5B}, depends upon the control voltage because the base-to-emitter voltage V_{BE} in both halves of Q_5 is derived from the control voltage, thus,

$$I_C = \beta I_S \exp(qV_{BE}/kT)$$

where β is the short-circuit current gain, I_S is the reverse saturation current, kT/q is 0.026 per volt at 27°C, and V_{BE} is scaled from the control voltage V in a voltage-divider network:

$$V_{BE} = VR_{TC}/(R_{IN} + R_{TC})$$

Therefore, the collector current is given as a function of the control voltage by

$$I_C = \beta I_S \exp\left[\frac{qR_{TC}V}{kT(R_{IN} + R_{TC})}\right] = \beta I_S K^V$$

In this expression, the scale factor K is just a substitution that replaces several terms: that is,

$$K = \exp\left[\frac{qR_{TC}}{kT(R_{IN} + R_{TC})}\right]$$

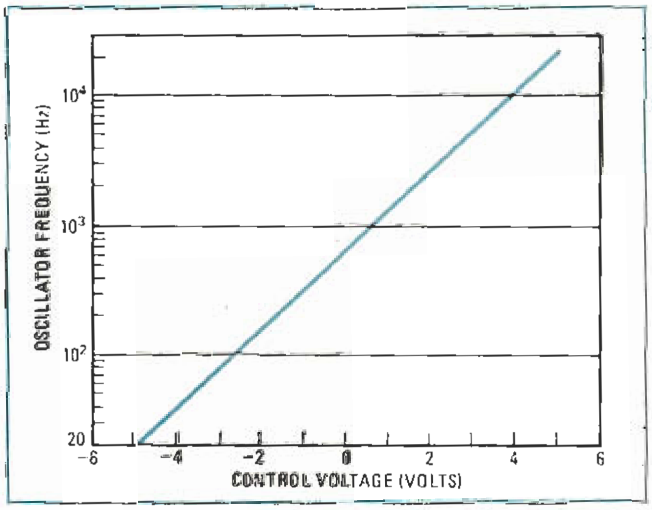
Current I_C is an antilog function (or exponential function) of voltage, and therefore the current source is called an antilog function generator.

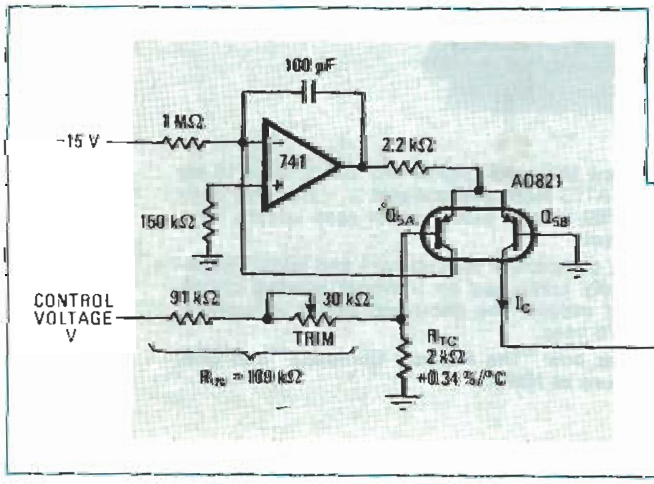
Because the frequency is directly proportional to I_C,

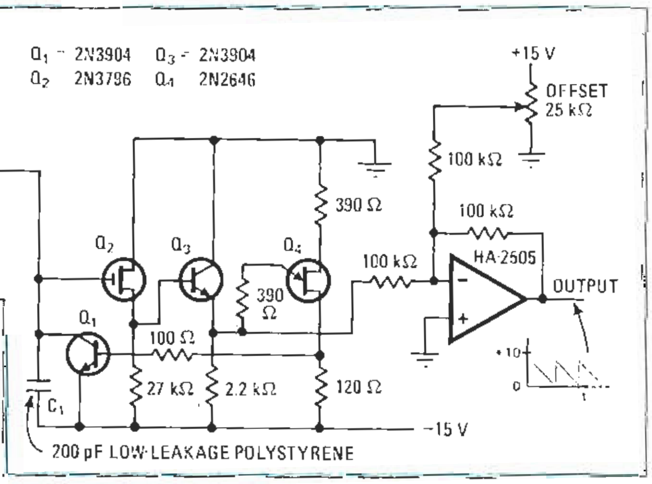
$$f \sim K^V = f_0K^V$$

where f_0 is the free-running frequency (i.e., the oscillator frequency when control voltage V is zero). The frequency f_0 depends on the parameters of Q_5, the firing voltage of Q_4, and the capacitance of C_1.

The value of scale factor K is set by the resistors R_{IN}







Voltage-controlled oscillator. Basic circuit is relaxation oscillator built around timing capacitor C_1 and unijunction transistor. Antilog function generator (in shaded area) supplies charging current that varies exponentially with control voltage. Tuning curve is 1-octave-per-volt straight line. If R_{IN} were 31.4 kilohms, tuning curve would be one-decade-per-volt straight line.

and R_{TC} in the divider network. If K is 10, the oscillation frequency changes by one decade when V changes by 1 V. With the resistance values shown in the circuit diagram, however, K is 2, so the frequency changes by one octave when V changes by 1 V.

The temperature sensitivity of I_C is compensated by the temperature coefficient of thermistor R_{TC}, +0.34%/°C, which is equal in magnitude and opposite in sign to the effect of q/kT in the expression for K. Thus, scale factor K is independent of temperature if the thermistor and Q_5 have equal temperatures. To ensure this condition, the thermistor is mounted in thermal contact with the header of Q_5.

The tuning curve shows the experimental performance of the VCO. The maximum departure from the straight-line relationship is only ±0.4% over the audio-frequency range from 20 Hz to 20 kHz. Outside that range, the voltage control becomes less precise. □

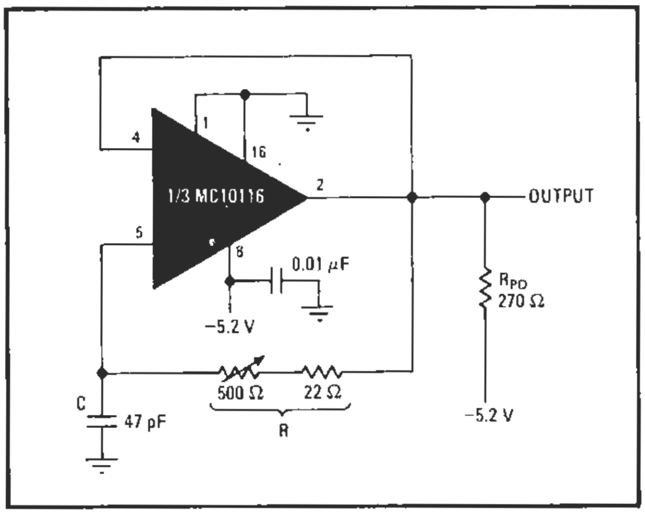
ECL IC oscillates from 10 to 50 MHz

by William A. Palm
Control Data Corp., Minneapolis, Minn.

One of the simplest of oscillators, the emitter-coupled-logic type outlined in Fig. 1, uses one third of the circuitry of an MC10116 ECL integrated circuit. Besides the IC, the only elements required for the oscillator are resistor R and capacitor C. The frequency of oscillation equals 1/3.4 RC.

Details of the oscillator are shown in Fig. 2. Transistor Q_1 is a constant-current source for the differential amplifier made up of Q_4 and Q_5. The output signal, taken from emitter-follower Q_2 at pin 2, is fed back to Q_4 as the oscillator reference voltage at pin 4. Thus, pins 2 and 4 are always at the same voltage, and they switch between the ECL levels shown in the waveforms.

Operation of the circuit is indicated by the waveforms of voltage at pins 2 and 4, and at pin 5. The capacitor charges and discharges through resistor R when pins 2 and 4 go higher or lower than pin 5. When pins 2 and 4



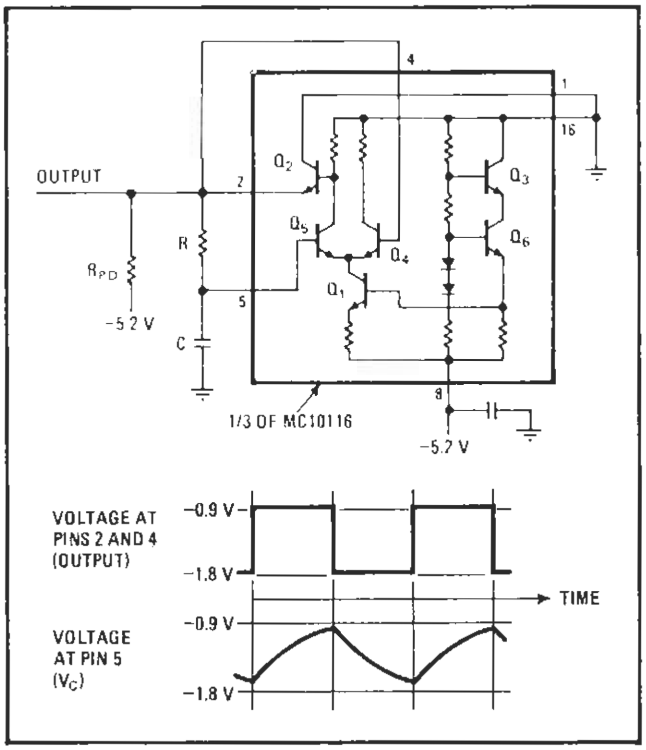
1. Oscillator. Extremely simple connections to emitter-coupled-logic IC result in an oscillator that provides square-wave output. Adjustment of R tunes frequency across a range of 10 to 50 MHz. Different R and C permit band-switching over a 10:1 range of frequencies.

are high, Q_4 conducts and Q_5 is off; the capacitor charges up until Q_5 starts to conduct, whereupon Q_4 cuts off and the voltage at pins 2 and 4 drops. The capacitor then discharges; when the capacitor voltage gets low enough, Q_4 starts to conduct, Q_5 cuts off, and the voltage at pins 2 and 4 jumps up. Thus, the capacitor voltage at pin 5 chases the voltage at pins 2 and 4, but never reaches their level because of the limited gain of the amplifier (approximately 8).

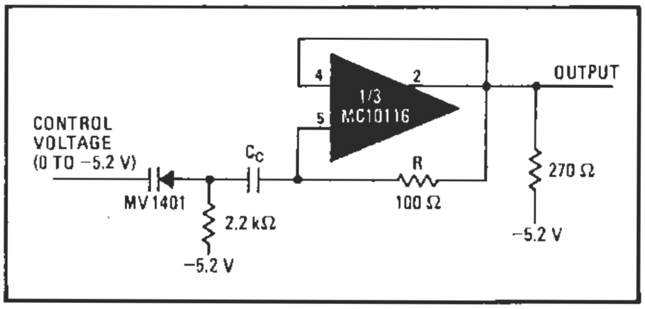
Values of R and C are not critical. The resistance of R can be as high as several kilohms or as low as 20 ohms. As R becomes smaller, pull-down resistor R_{PD} must also become smaller to keep emitter-follower Q_2 in conduction. For maximum oscillation frequency, R can be 20 ohms and C a few picofarads. The adjustable oscillator in Fig. 1 oscillates at frequencies in the range from 10 to 50 megahertz. Other choices for C and R can produce osillation at frequencies ranging from audio to vhf.

The frequency equation is inaccurate at the upper ranges because of propagation time, stray capacitance, and the difference between charge and discharge impedances presented at the output. It is desirable to buffer the oscillator through a second stage of the ECL IC.

Use of a varactor diode in place of capacitor C, as shown in Fig. 3, makes the circuit a voltage-controlled oscillator. A varactor with a capacitance range of 10:1, such as the MV1401, works well. Coupling capacitance C_C can be much larger than the diode capacitance, or can be chosen to limit the range of deviation. The oscillator in Fig. 3 operates at (15 ±10) MHz for a voltage swing of 0 to −5.2 volts at the VCO input. ☐



2. Operation. Circuit diagram shows how ECL oscillator operates. Output voltage is fed back to Q_4. Capacitor voltage at pin 5 tries to reach voltage at pin 4, causing output to switch between different ECL levels. Oscillator can never hang up.



3. Voltage tuning. Varactor diode in place of C makes circuit a voltage-controlled oscillator. This VCO operates at (15 ±10) MHz.

eas of the transistor junctions are trimmed to suit, the two currents (the input current and the mirror current) will be very nearly identical, and this identity will hold good over a wide current and temperature range. Although this is an integrated arrangement, discrete transistors can be used if their characteristics are reasonably closely matched.

In several circuits of the type shown in Fig. 4, the transistors used in the mimic circuit were BC184s in which the base-emitter forward voltage drop was matched by selection to about 10mV at 50μA forward current (i.e., say 0.58V to 0.59V). This is inconvenient, but not difficult if one has a voltmeter and six or eight similar transistors to choose from. Although BC184s were used, any other similar small signal silicon devices would serve just as well.

The performance of the circuit shown in Fig. 4 is given in Fig. 5. The relationship between the control voltage and the frequency had a linearity better than 1% per MHz, and the frequency stability was as good as that of the author's signal generator during a six hour measurement period.

In view of this encouraging performance, a means was sought for avoiding the inconvenience of having to select a matched pair of "current mimic" transistors, without the expense involved in the use of a matched-pair device. The solution was found in the use of an i.c. transistor array of the type contained in the RCA CA3046, of which the internal circuitry is shown in Fig. 6. In this particular case the array contains all the active components needed to make the v.c.o. circuit, including a matched pair of transistors. The circuit arrangement is in Fig. 7, for which the necessary interconnections across the base of the CA3046 are shown in Fig. 8.

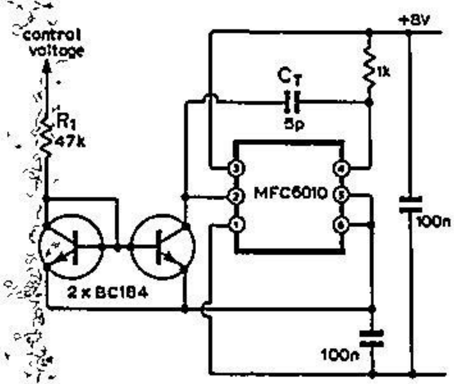


Fig. 4. Circuit of the v.c.o. using discrete transistors for the current mimic circuitry.

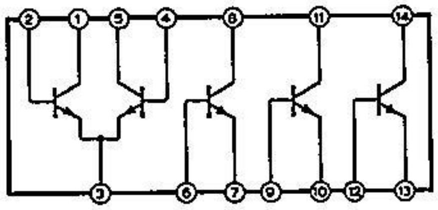


Fig. 6. Layout of transistors and pin connections for the i.c. transistor array contained in the RCA CA3046.

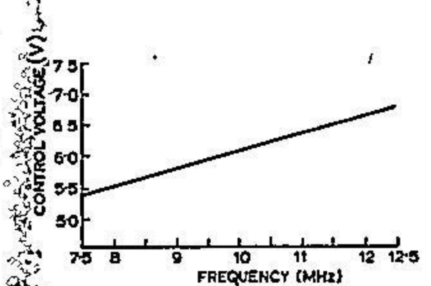


Fig. 5. Performance of the circuit shown in Fig. 4.

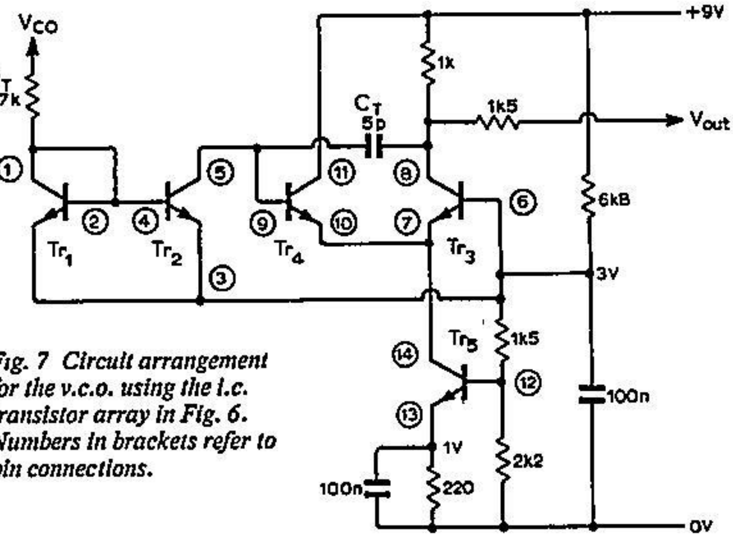


Fig. 7 Circuit arrangement for the v.c.o. using the i.c. transistor array in Fig. 6. Numbers in brackets refer to pin connections.

Fig. 8. Connections to the CA3046 which complete the circuit shown in Fig. 7. The view is from below.

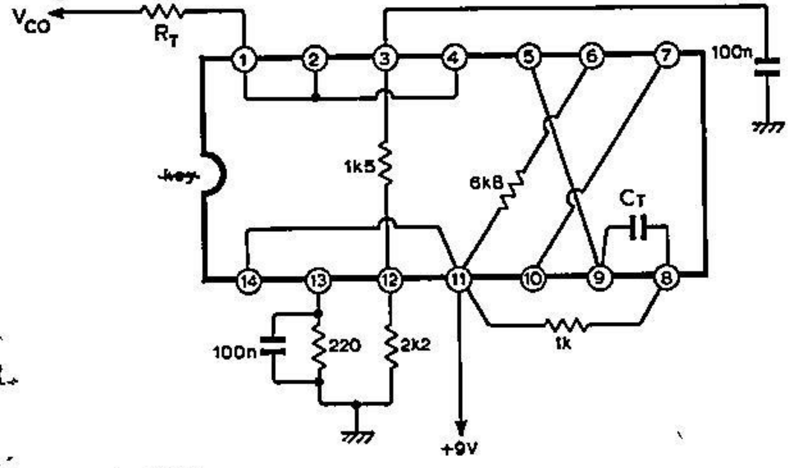
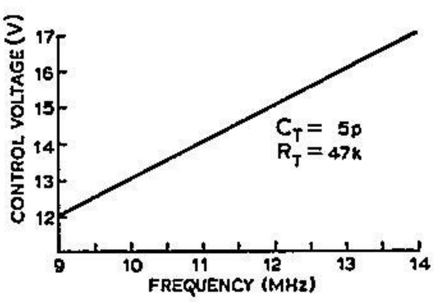


Fig. 9. Control characteristic of the v.c.o in Fig. 7.



The performance of this circuit for a timing capacitor of 5pF, and with the other values as indicated, is shown in Fig. 9. The linearity of this arrangement is as good as that of the circuit in Fig. 4, but the long term stability of the Fig. 4 circuit is slightly better. Several CA3046 units were tried and gave identical free running operating frequencies.

Typical applications

A simple phase locked loop configuration built around this v.c.o. and suitable for use as a high quality f.m. demodulator, using an f.e.t. as a synchronous chopper type phase sensitive detector, is shown in Fig. 10. An amplitude limited input r.f. signal, of nominal 10.7MHz frequency, and of about 500mV amplitude is desirable for correct operation of the system. The output a.f. signal will be about 20mV for 75kHz deviation, with a second harmonic distortion content of about 0.07%.

An arrangement usable as a low distortion frequency modulated signal generator if a suitable low distortion sine-wave modulation signal is applied, or as a "wobbulator" if a sawtooth input signal is provided, is shown in Fig. 11. Increasing the capacitance of the timing capacitor will provide a proportional reduction in operating frequency, allowing the system to be used, if required, down to audio frequencies, as a voltage controlled oscillator in electronic organ and similar applications.

As a final provocative thought, since it is possible to build voltage controlled oscillators (and phase locked loop demodulator systems containing these) whose linearity, over the 75kHz bandwidth normally used for f.m. transmissions, is better than 0.1%, by some margin, is not the ball now in the court of the broadcasting authorities to take note of this, and improve their f.m. transmission quality?

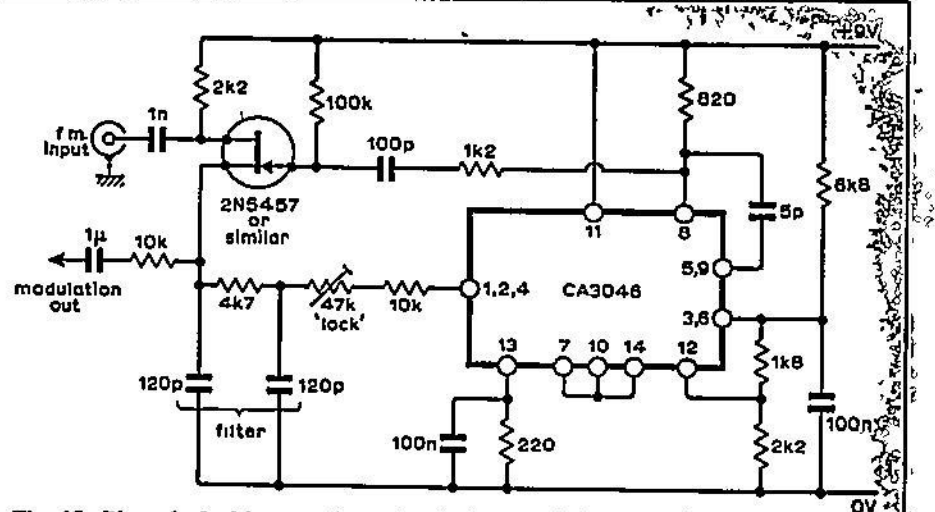


Fig. 10. Phase locked loop configuration built around the v.c.o., suitable for use as an f.m. demodulator. The f.e.t. is used as a synchronous chopper type phase sensitive detector.

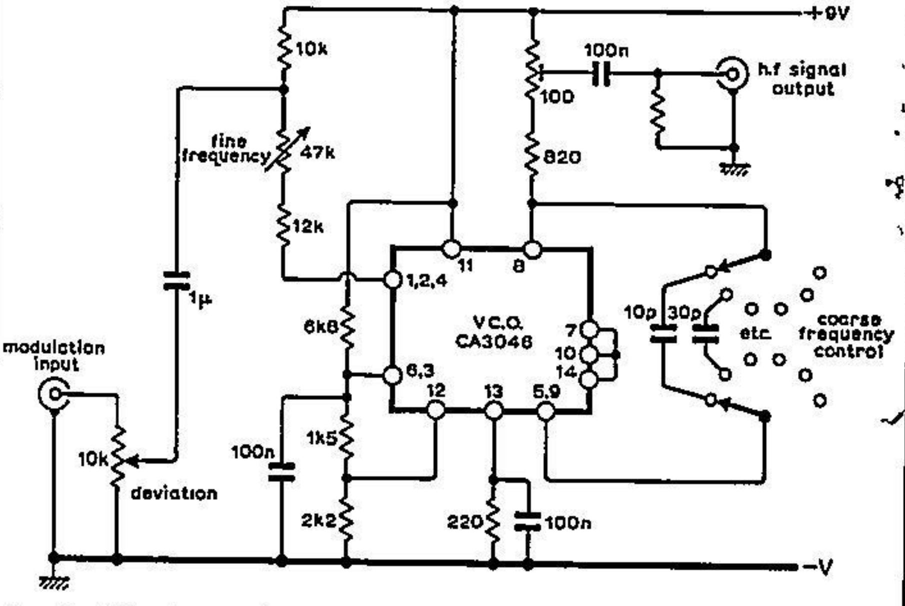


Fig. 11. Using the v.c.o. in an arrangement for a low distortion f.m. signal generator, or as a "wobbulator".

Books Received

Noise and Modulation are two books by F. R. Connor and are respectively the fifth and sixth in a series of books on introductory topics in electronics and telecommunications. They are texts designed to assist students preparing for university degree examinations or for courses at a similar level "Noise" presents a survey of the various conditions of electrical noise followed by mathematical ideas concerning random variables. Circuit noise, noise factor and noise temperature are then considered. Finally, there is a comparative study of some important communication systems. "Modulation" provides a broad outline of the most important methods used in practice. Analogue methods such as amplitude and frequency modulations are first considered and this is followed by pulse modulation and the various types of pulse modulation. There is a final chapter on demodulation at the receiver The material in both books is related to modern practice and a number of worked examples are included. Both books cost £1.10. and have approximately 100 pages each. Edward Arnold Ltd, 25 Hill Street, London W1X 8LL.

The Directory of Instruments, Electronics & Automation 1973 (ninth edition) contains collated information on manufacturers, trade names, equipment and components in the electronics industry. Sections come under the headings diary of events, association addresses, who buys, U.K. agents, trade names, manufacturers' addresses and a buyers' guide. Price £7. Pp.328 Morgan-Grampian (Publishers) Ltd., 30 Calderwood Street, London SE18 6QH.

Recent additions to the Foulsham-Tab books on electronic topics and published by W. Foulsham & Co. Ltd., Yeovil Road, Slough, Bucks, are:

- How to Solve Solid State Circuit Troubles by Wayne Lemons, Price £1.75. Pp.304.
- How to Build Solid State Audio Circuits by Mannie Horowitz. Price £1.75. Pp.320.
- How to test almost everything electronic by Jack Darr. Price £1.30. Pp.160.

Which Way Does Current Flow?

Some thoughts arising from recent correspondence

by "Cathode Ray"

It would probably be flattering myself excessively if I imagined for one moment that, when Messrs Banthorpe, Ellis and Whitehead[1] appealed for the direction of an electric current to be deemed to be the same as that of the electrons composing said current, it entered the heads of any of them to think "Well, anyway, old Cathode Ray will back us up". If, however, the question of what I would be expected to think about it had been put to them, as a minor matter of academic interest, they might confidently have claimed me as a potential ally, since in so far as I am well known at all I am well known as one who decides on circuit conventions by processes of logic and common sense rather than by what is generally accepted. They might have quoted as evidence my strong support for the heretical doctrines of M. G. Scroggie on phasor diagrams and their mass of related conventions. Beside this complex thesis, the case for abolishing the conventional direction of current flow in favour of the direction of electron flow (they would say in chorus) is simplicity itself as well as being exquisitely logical and commonsensical. So Cathode Ray could not but stand shoulder to shoulder with them.

Flows, fields and tracks

It is true that their case was severally put forward in terms that nearly brought tears to my eyes. I'm sure they meant well. And I hope they won't take it too hard when they find that their idol (self-flattery again!) has feet of clay (Daniel 2, 41-43). But it is a fact that I find myself having more in common with what Thos. Roddam divertingly proclaimed from the next bed to mine in the Geriatric Technologists' Home, as well as with the plain Yorkshire words of A. Parnham, also recorded on the p.386 already cited. I hope this revelation of my reactionariness will not cause a mass defection from the ranks of my followers (if any) — at least, not until they have read right through to the end, which is not far distant.

Roddam argues against reversing the usual convention (i.e., "current" opposite to electron flow) on the grounds that (a) to do so would cause a great upset (at which he hints by pointing out that among other things it would make nonsense of all diode and transistor symbols), and (b) (although one suspects that he personally might find such an upset quite amusing) there is really no need for it if only we stopped bothering our heads unnecessarily with charge carriers, which can safely be left to the electronic device makers, and dealt simply in fields and "current tracks".

But you may not be ripe for accepting such a revolutionary plan (and I wouldn't blame you). In that case you must meditate on the fact that not all electric charge carriers are electrons. In this respect electricity differs fundamentally from air and water, held up by Banthorpe as examples for it to copy. And although Ellis may not be able to satisfy his commendably inquisitive students on *why* there are two kinds of current (unless he has a hot line to the Creator) he cannot deny the fact. A great many carriers are holes and positive ions. So the choice of which to regard as positive for the purpose of specifying direction of current flow is arbitrary anyway. Even if we yielded to the entreaties of the enemies of the current (in two senses) convention and overthrew it we would not rid ourselves of the anomaly of some charge carriers flowing the wrong way.

The answer that would undoubtedly emerge from Messrs Banthorpe, Ellis and Whitehead is that, as practical current carriers, electrons are in a large majority, having in metallic circuits at least a virtual monopoly; and that should decide the matter. The sacred cause of Democracy and all that. Students would still have to face the fact of current carriers flowing in the opposite direction to the currents they carried, but less often than at present, and every little helps. Whether that little would be enough to justify reversing very nearly all the books is a big question, however.

Perhaps it would help to answer it if we went on to a point that the current revolutionaries don't seem to have considered, or if they have then not enough. Suppose we did what they said and agreed to call the positive direction of electric current the direction in which the electrons composing that current were flowing, or, if the flow was of positive carriers, the opposite direction. Would students be any less confused than they are now if they were told that the positive direction of current was the direction in which negative charges were flowing, or opposite to the direction in which positive charges were flowing? Or that (as suggested by Banthorpe) current flows from negative (i.e., a deficit) to positive (surplus), like water doesn't flow from the bottom of a well to the top of a hill?

Too much, too late

On the reasonable assumption that the students would be even more confused by this, the revolutionaries would be driven to deciding to call electrons positive charges. That would have been an excellent idea 75 years ago when electrons were discovered. But now? The imagination boggles. As my fellow geriatric has pointed out, all rectifier, diode and transistor symbols would need to have their arrow heads reversed. The electric fields would have to be changed around too. All those + and − things in books on electronics would have to be interchanged. There would be great fun in deciding whether your car battery had been made before or after R Day and so whether red should be taken to mean black and vice versa, or not. And what about Fleming's right and left hand rules? And the corkscrew rule? Would we have to reverse magnetic field conventions? As in the administration of VAT, problems would multiply as one went along. Before we were finished, the operation of changing Britain over to the right-hand rule of the road would look simple and straightforward.

Believe me, I'm truly sorry to be numbered with the reactionaries, but in this matter (as the key worker says when he downs tools for a 50% rise) I have no alternative.

Reference

[1] *Wireless World* June, 1973, p294 and August, 1973, p.386

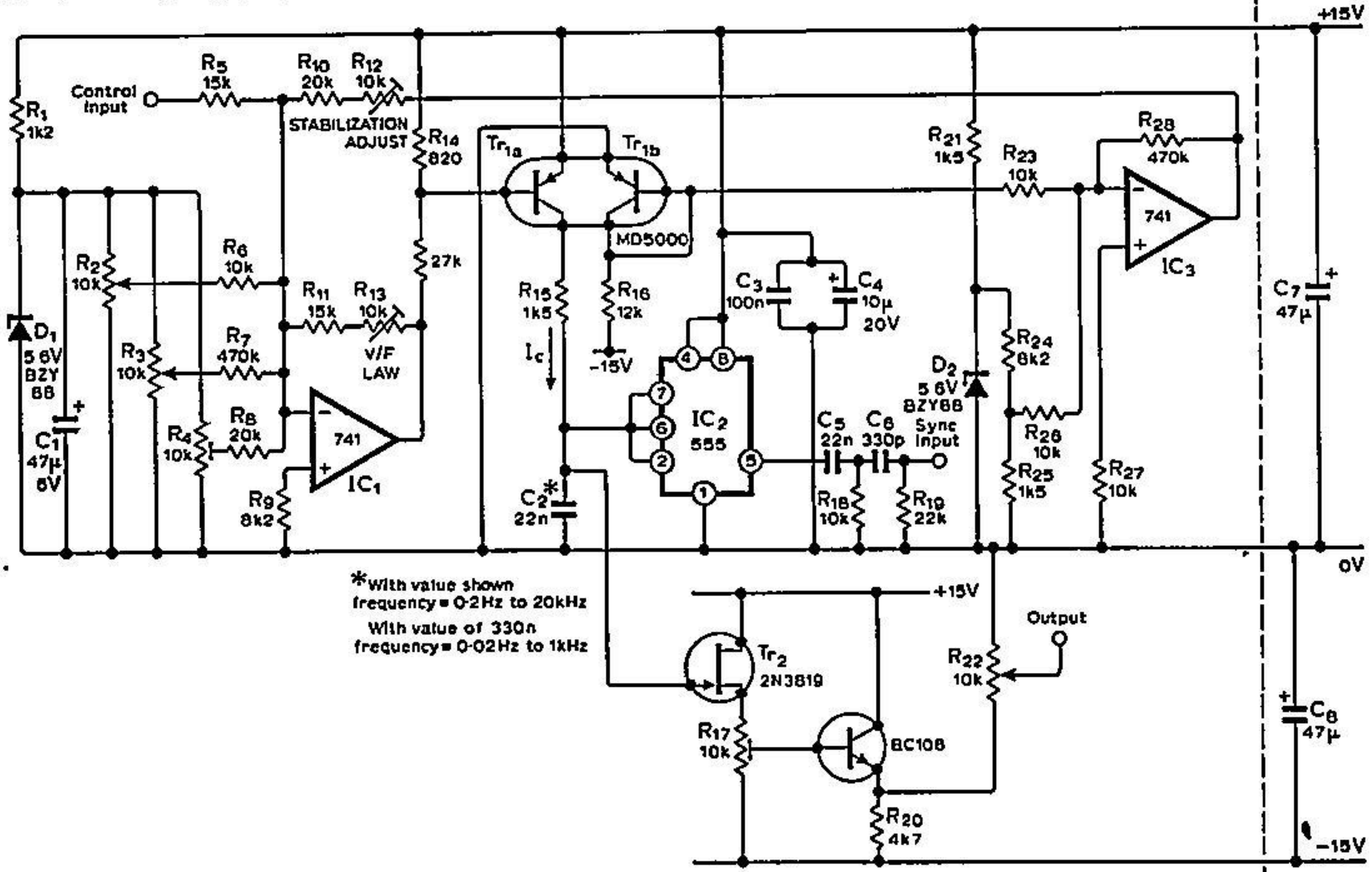
Voltage controlled oscillator

This exponential law voltage-controlled oscillator, which produces a linear ramp output waveform, is based on a circuit idea by J. L. Bride, *Wireless World* June, 1976. This design is perhaps more suitable for use in sound synthesizers because it has high frequency stability and a provision for synchronization to another oscillator.

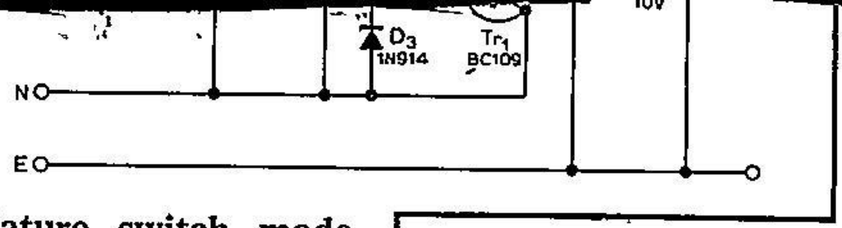
The 555 timer is used in the astable mode, with Tr_{1a} supplying a constant current to C_2. If the temperature rises, the V_{be} of Tr_{1a} and Tr_{1b} falls at a rate of about 2mV per deg C. The fall in V_{be} of Tr_{1a} is fed back via IC_3 to IC_1 and causes the applied V_{be} of Tr_{1a} to fall which keeps I_C constant. Preset R_{12} adjusts the amount of feedback, and hence the temperature stability. The circuit exhibits a maximum instability of ±0.1% to ±0.2% over a 24 hour period. Both R_{12} and R_{13} should be multi-turn components.

A synchronizing square wave signal may be fed in at R_{19} with an amplitude of 5 to 10V pk. This signal is differentiated and the resulting spikes control the threshold voltage of the 555. Resistor R_4 sets the minimum frequency, R_{22} sets the average output level to zero volts, and R_2, R_3 provide coarse and fine frequency controls respectively. Equivalents for the MD500 are a BFX11 or BFX36. If either of these are used, R_{25} should be reduced to compensate for the lower V_{be}

T. W. Stride,
St. Albans,
Herts.



*With value shown frequency = 0.2Hz to 20kHz
With value of 330n frequency = 0.02Hz to 1kHz



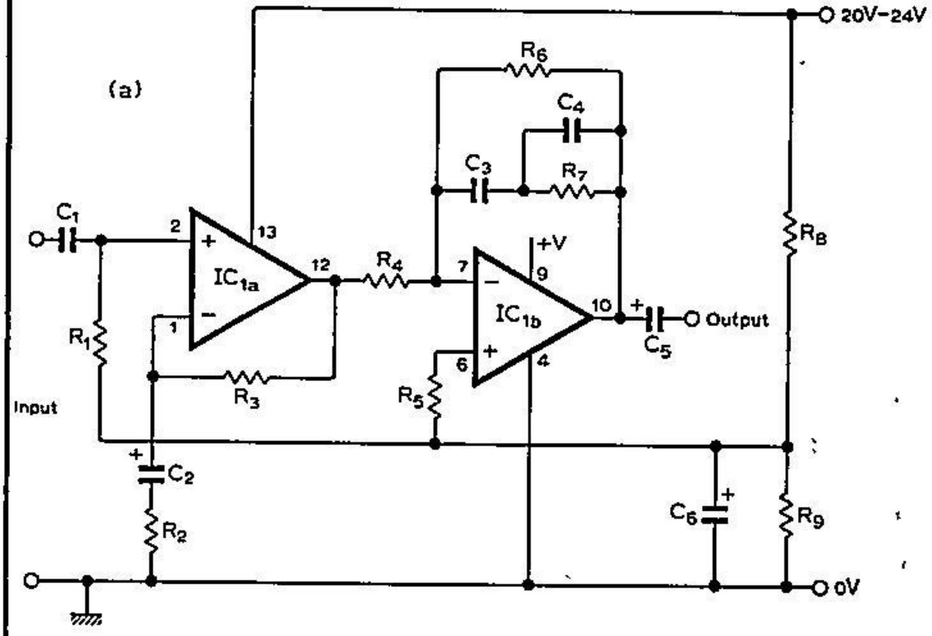
Miniature switch mode power supply

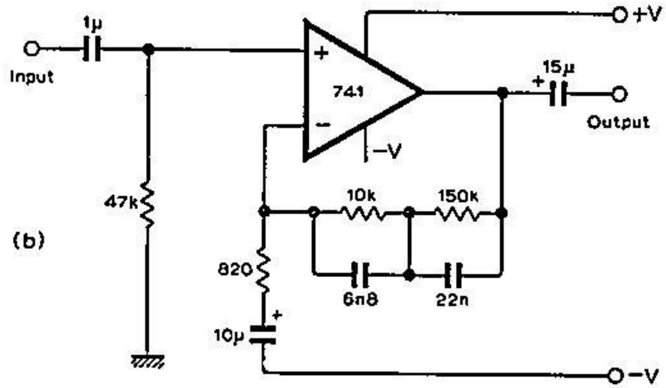
This unit was designed to fit into the battery compartment of a small transistor radio or calculator. In operation C_1, D_1 and D_2 produce 15V d.c across the smoothing capacitor C_2 This forms the supply for a one transistor inverting circuit and D_3 returns the magnetising current to the supply during the negative half of a cycle. The output is isolated from the mains input and, provided that the transistor and D_1 have sufficient heat sinking, will stand an indefinite short or open circuit An inverter frequency of 13kHz permits the use of a small transformer such as the Phillips P14/8 337 pot core. Wire size should be 37 gauge and the primary windings are bifilar. The unit requires an earthed shield to reduce radiated switching noise

M. Faulkner,
Queanbeyan, N.S W ,
Australia.

Low noise amplifier

The circuit shown in Fig (a) offers a 12dB improvement in signal to noise ratio compared with the more traditional circuit in (b).





Dynamic VCO test detects V-f nonlinearities

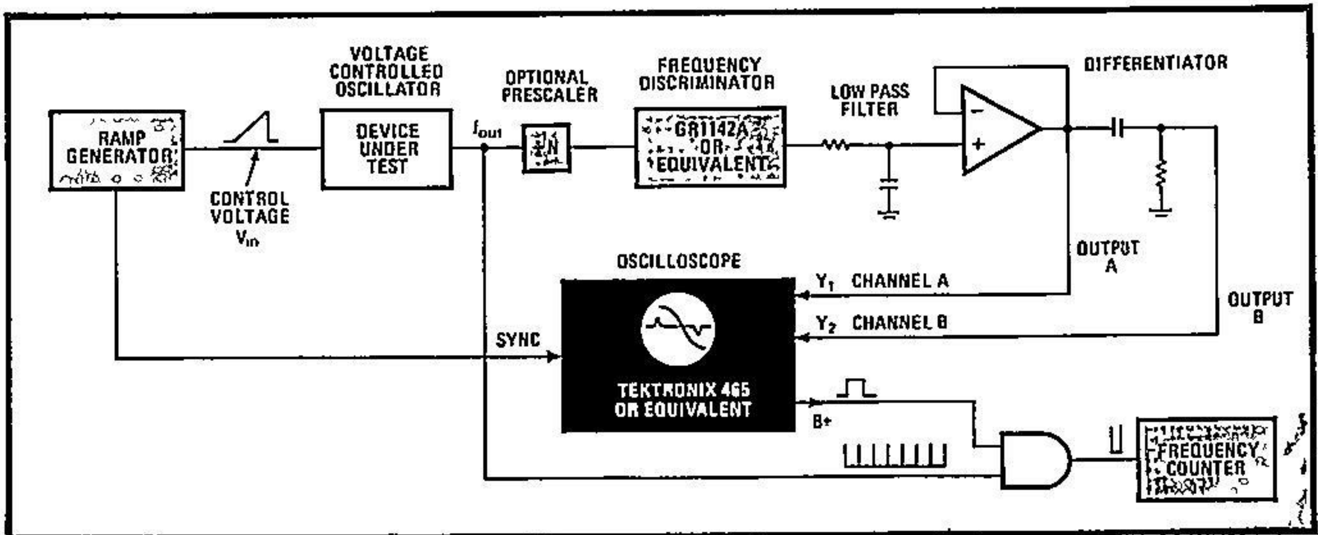
by Hanan Kupferman
Century Data Systems, Anaheim, Calif

Checking the dc response, or static behavior, of a voltage-controlled oscillator is easy enough to do, requiring only the plotting of output frequency versus a discrete set of control voltages. But more often than not the dynamic, or ac, response is the parameter of interest, especially if a small nonlinearity in the voltage-to-frequency response exists. Fortunately, running a dynamic check is relatively uncomplicated, as the method described here makes evident. With it, nonlinearities are quickly spotted, and the frequency at which the anomalies occur can be readily measured

As can be seen, the input of the VCO is driven by a ramp voltage that sweeps it over its range of frequencies. Its output is then introduced into a frequency discriminator, which generates a voltage corresponding to the VCO's dc response. If the range of the discriminator is limited, a divide-by-N module should be used to divide down the output frequency of the VCO beforehand.

The discriminator's signal is then applied to one vertical input (channel A) of the scope Appearing at channel B is the differentiated version of the signal at output A. Thus the scope displays the VCO's voltage-versus-frequency/time characteristic and simultaneously shows if the change in its output frequency per unit voltage is other than linear The magnitude of the nonlinearity shown on channel B will be proportional to the amplitude of the positive- or negative-going spike created by the differentiator.

The frequencies at which nonlinearities occur can be measured by placing the scope in the A-intensity mode to intensify the part of the trace where the irregularity is suspected (that is, the region of the curve A corresponding to the location of the spike on channel B) The duration of the pulse output at the scope's B+ port during each scan, corresponding to the intensified area of the curve selected, is thus used to gate the output of the VCO through to the frequency counter. Note that the accuracy of the measurement will be inversely proportional to the width of the area that is intensified ☐



Dynamic response. Tester readily spots nonlinearities in VCO's voltage-to-frequency curve Channel A of scope displays dc response, channel B the dynamic information, whose spike amplitude is proportional to the magnitude of the nonlinearity present. Frequency at which irregularity occurs is measured by intensifying portion of curve A at which spikes appear, in order to generate gating pulse for counter