Optically coupled v.f.o.

A method for complete isolation of a high-frequency oscillator from its load, using a l.e.d./photodiode-transistor combination

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The method of transmitting information by amplitude modulation of a beam of light is not new (e.g. "Light-emitting diode —application to a short-path television link", *Wireless World*, Aug., 1964) Normally the light is pulsed or voice-modulated, but the transmission of high frequencies has been limited by the characteristics of the incandescent lamp. With the introduction of the light-emitting diode, the frequency range of the transmitting element was extended well above the audio spectrum. This was followed by the production of the optically coupled isolator (o.c.i.), which has the transmitting element (a l e.d.) and the detector (a photodiode, or phototransistor) in close proximity within the same package. Primarily, the o c.i. has been developed for d.c. isolation in digital and analogue circuits, in order to eliminate ground-loop currents They may also be used as replacements for pulse transformers and mechanical relays. It is only recently, with the introduction of high-speed o.c.is, such as the 5082-4350 series and the 5082-4360 device by Hewlett Packard, that the useful frequency range can be extended to beyond 10MHz. This is quite sufficient for most v.f.o. applications in amateur equipment.

The prime consideration in the construction of a variable-frequency oscillator is the long-term frequency stability with respect to changes in ambient temperature. Attention to careful layout and choice of components can reduce this problem to acceptable levels. A problem not so easily dealt with is the frequency instability of the v.f.o due to a varying load. For example, when the v.f o. is directly coupled to a high-level mixer stage in a receiver, or a modulated/keyed stage in a transmitter. The usual procedure is to place one or more buffer stages between the oscillator and the fluctuating load. This can introduce instability and noise because of the loose coupling to the oscillator The optically coupled isolator offers a simple solution.

The operation of the 5082-4350 series is as follows A light-emitting input diode is optically coupled with a p-n photodiode which drives a high-speed transistor. The GaAsP input diode emits photons in proportion to its forward current. These photons are received by the p-n photodiode detector and amplified by the transistor. The current transfer ratio

$$\frac{I_{collector} \times 100}{I_{l.e.d.}} \%$$

is typically 11% for the 4350 device and 22% for the 4351. The 4360 package incorporates a linear amplifier driving a Schottky transistor in the output circuit, and exhibits a current transfer characteristic of typically 600%, with an improved frequency response (20MHz).

Although the 4360 is the best choice for simplicity of design, because of the high gain it offers, the 4350 device was chosen as the most practical for amateur use. Consequently, both the circuits described in this article use the low-cost 5082-4350 device.

Circuit description

An emitter-coupled Colpitts-type oscillator is used for the v.f.o. The bipolar transistor chosen for Tr_1 is the low-noise 2N3707, which in the experience of the author, produces an oscillator with excellent stability when used in this configuration. The v.f.o. can operate over the range 1.5 to 5.7MHz, without changing either of the feedback capacitors in the emitter-base circuit of Tr_1. As this transistor is used in the common collector mode, the l e.d. section of the o.c.i. can be placed in the collector supply with little effect on the operation of the oscillator. The l.e.d. is forward biased by the 6mA current flowing through Tr_1, resulting in a d.c. collector current in the photodiode transistor of typically 0 7mA.

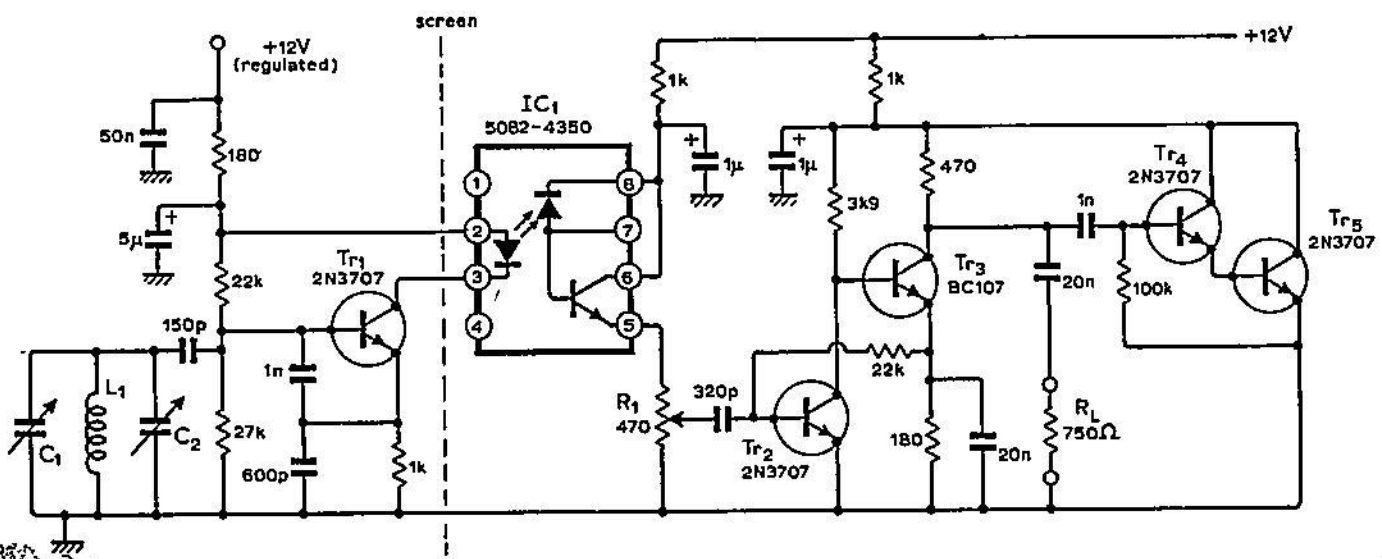


Fig. 1. Oscillator, optically coupled isolator and first stage of amplification.

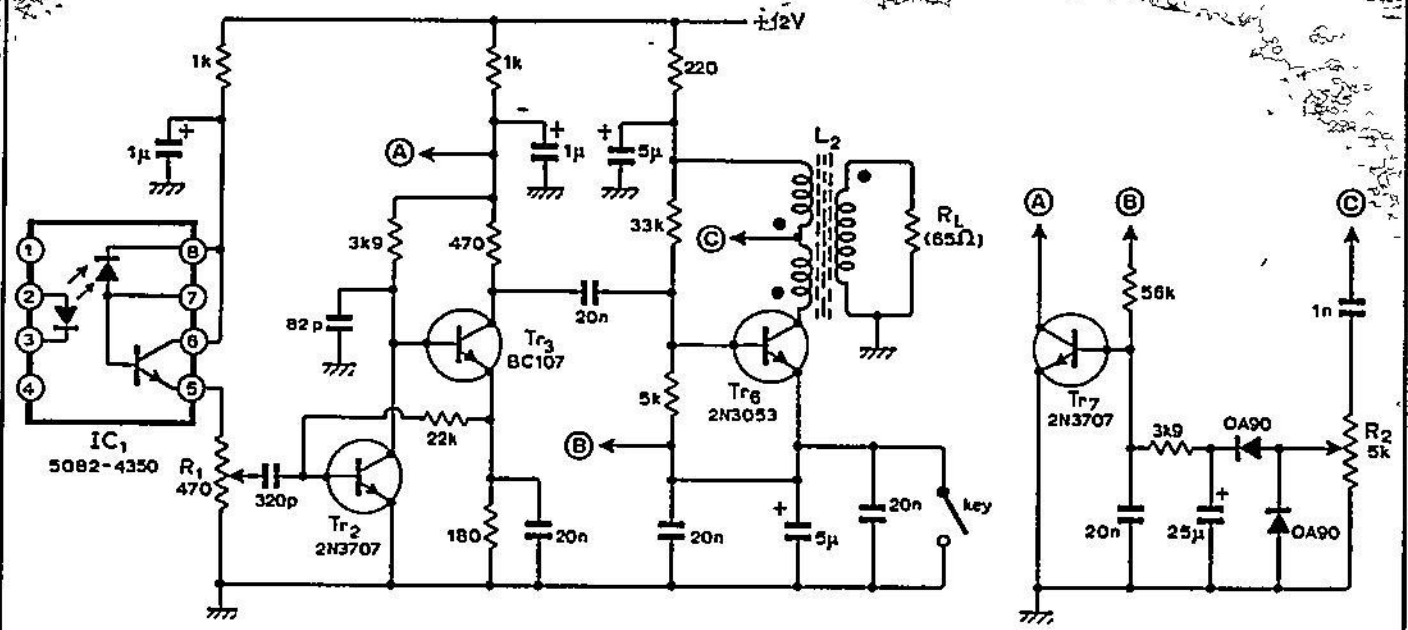


Fig. 2 Final circuit with preamplifier, output amplifier and automatic limiting control (oscillator omitted).

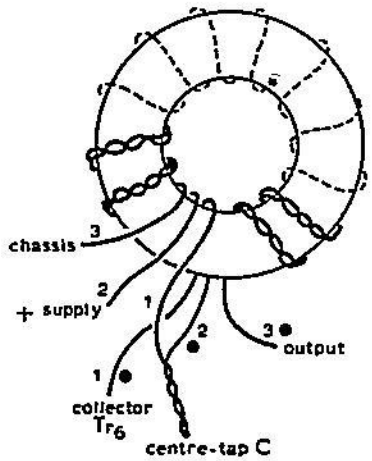
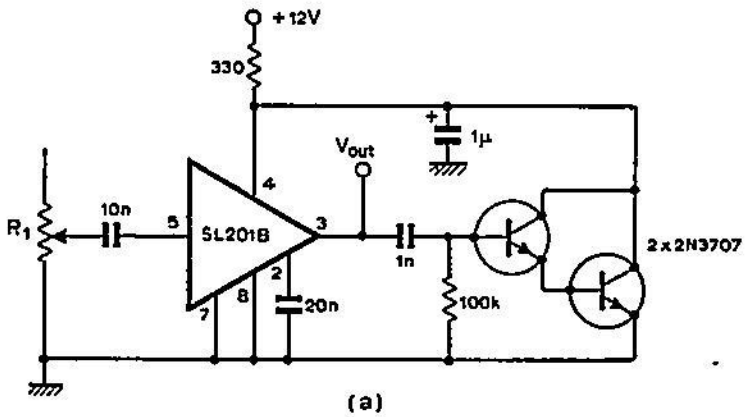


Fig. 3. Construction of the broadband output transformer for Tr_6



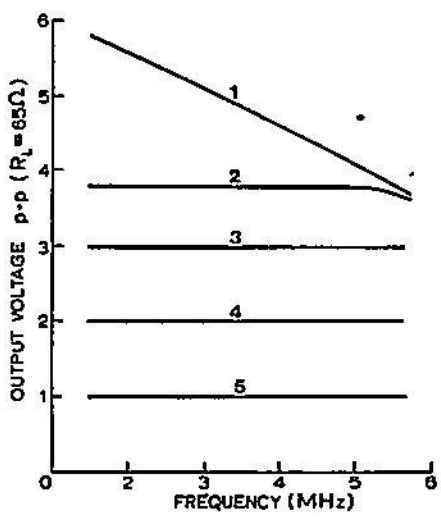


Fig. 4. Output curves of Fig. 2. Voltages are peak-to-peak across the secondary winding loaded with a 65Ω carbon resistor.

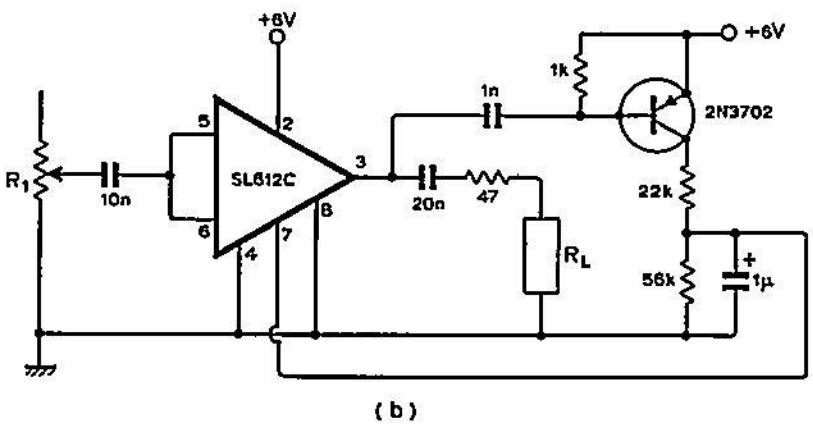


Fig. 5. Alternatives to Fig. 1 using integrated circuits.

The output stage of Fig. 1 is a broadband amplifier with d.c. coupling between Tr_3 and Tr_5. The output is maintained (±1% over the frequency range of the v.f.o.) at about 2V peak-to-peak, by the automatic limiting control (a.l.c.) action of Tr_4 and Tr_5. Both the v.f.o. and the amplifier stage are fed from a common 12V regulated supply.

For greater output, a second broadband amplifier can be added, Fig. 2. This increases the output to 25mW into 65Ω from 1.5 to 5.7MHz. For simplicity, the output from Tr_5 is coupled via a capacitor to the base of Tr_6. The method of biasing Tr_6 is unusual for an output stage, but provides protection against overdrive or v.h.f. instability from a reactive load. The power output may be increased considerably by decreasing the value of the 220-ohm collector supply resistor for Tr_6, but care should be taken not to exceed the ratings for the transistor by operating into an incorrect load. The collector-to-output matching device is a broadband transformer, constructed as shown in Fig. 3. The output voltage may be kept constant by the action of the a.l.c. circuit, Tr_7 and associated diodes. The output voltage is adjustable by the setting of Tr_2.

The circuit of Fig. 2 also provides for keying of the output by "lifting" the negative rail to Tr_6, and simultaneously switching Tr_7 on, via the 56kΩ resistor to the base of Tr_7. The 5μF capacitor and the a.l.c. network produce a pleasant keying characteristic.

Modulation may also be applied to the base of Tr_7, with forward bias provided by adjustment of R_2. The setting of R_2 will be governed by the depth of modulation required.

Construction

The oscillator section should be built with particular attention to physical ruggedness and good-quality components. The oscillator should be screened from the amplifier. The prototype was built on a printed-circuit board 6cm wide by 11cm long, and this was mounted 1cm above an earth plane. Because of the relatively high r.f. currents present around Tr_6, the bypass capacitors should not be omitted from the Tr_6 emitter rail. In the circuit of Fig. 2 an 82pF capacitor may be necessary from the base of Tr_5 to ground to ensure complete stability. This should not be required in the circuit of Fig. 1.

L_1 is 42 turns of 36 s.w.g. enamelled copper wire, close wound on a 6mm former, with an adjustable iron-dust core, and metal screening can. C_1 and C_2 are chosen to give the required tuning range in conjunction with adjustment to the core of L_1.

L_2 is a broadband transformer comprising 14 turns of 28 s.w.g. enamelled copper wire, trifilar wound on a 12mm o.d., 6mm i.d., 3mm-thick ferrite ring, Fig. 3. The three strands of wire are twisted together, for tight coupling, before winding. The connections to the six free ends are shown in Fig. 3.

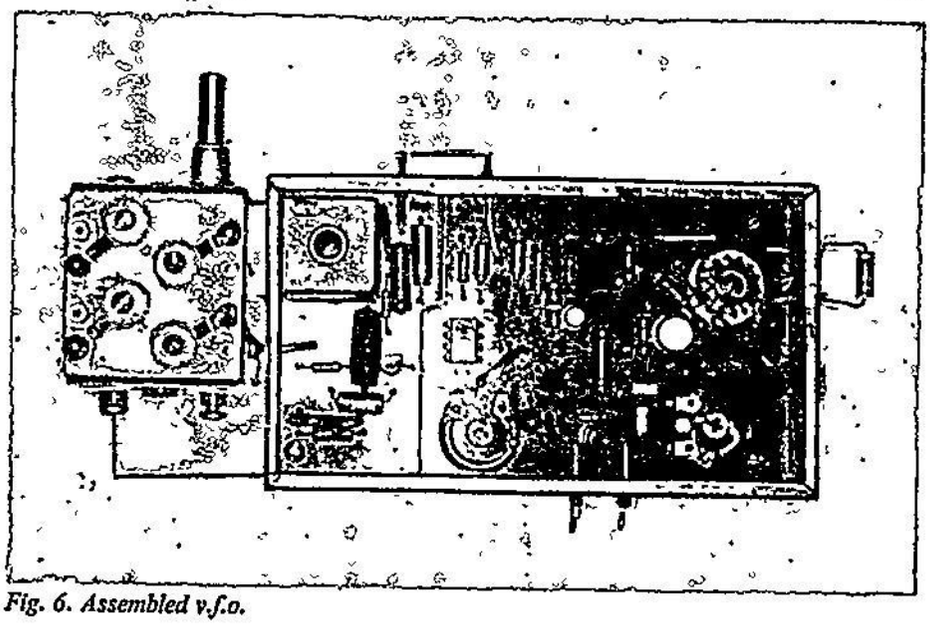


Fig. 6. Assembled v.f.o.

Conclusion

The 5082-4350 device can provide a useful output without further amplification. When used in the common emitter configuration, with a 470Ω resistor in the collector circuit of the photodiode transistor, an output of 200mV p.-p. was obtained at 5MHz. (The d.c. current transfer ratio of the o.c.i used in the prototype was 13% at 6mA input.) Greater output was obtained at lower frequencies. However, if the frequency range of the v.f.o. is to be large, the output will need to be regulated and further amplification will be required.

The performance of the circuit in Fig. 2 is shown in Fig. 4. The uppermost trace is the output with no a.l.c. applied. The lower traces are with minimum effective a.l.c. (2) over the range 1.5 to 5.5MHz, and with maximum a.l.c. (5) applied. The output can be reduced further by taking the reference voltage (Fig. 2) from the collector of Tr_6. Although the output waveform of the prototype appeared "clean", a low-pass filter should be used if the output of the v.f.o. is to be fed directly to an antenna

Keying of the final amplifier, and also intermittent disconnection of the 12V supply to the amplifier section, produced no detectable shift in oscillator frequency. A crystal oscillator was used as a reference because the large changes in input signal to the monitor receiver (a Lafayette HA800 A) were sufficient to "pull" the first oscillator of the receiver.

Although the final design is relatively complex, it must be realized that if a narrow band is to be covered (e.g. the c.w. band of 80 metres) then tuned inductors may be used to advantage. However, the present design can be used as a v.f.o. for all of the 160- and 80-metre bands by the switching of C_2 only.

For those constructors who prefer to use integrated circuits, the construction may be simplified by using an i.c. for the linear amplifier section. The circuit around Tr_2 and Tr_3 may be replaced by the Plessey SL201B d.c. coupled 10MHz amplifier (Fig. 5(a)). However, the current drain is increased by 4 to 5mA, and the supply resistor from the 12V line is reduced to 330Ω. A circuit was also built using the more expensive SL612C (current drain typically 3.5mA at 6V). This is a low-distortion broadband amplifier with 70dB a.g.c. capability, and the simple circuit shown (Fig. 5(b)) gave a very good performance.

The various circuits discussed in this article have been used to demonstrate the practicability of using an optically coupled isolator device such as the H.P. 5082-4350, as probably the ultimate solution to the isolation of a variable-frequency oscillator in all types of communications equipment.

Sixty Years Ago

Whoever it was had the idea of using "wireless" as a means of communication between Australian farmers and central stations, Mr W. King Witt, vice president of the Wireless Institute of Victoria, is the first reported propounder of the notion in *Wireless World*. In an issue largely preoccupied with news of the war, there appears an unsigned report on a tour carried out by Mr Witt, after which he was moved to point out that the use of wireless would reduce "the terrors and disadvantages of loneliness".

"In illness or emergency of any description it would only be necessary for the farmer to seat himself at this instrument and tap out with the key before him his cry for help or his order for a new cultivator. From the transmitter the waves would flash like ripples in the ether, to be gathered in by the cobweb of wires at the central station; and in half the time that would ordinarily be taken, help would be at hand, or the new machine on the road. And, maybe, in the evenings the wireless would crackle busily with private gossip or invitations from one to another 'come round and see us' Thus would loneliness be banished!"

According to the Australian High Commission, there are now around 8,000 licensed operators, working with nine central stations.