Increductor® Notes #2

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DIRECTED TO THE THEORY AND USE OF HIGH FREQUENCY SATURABLE REACTORS

IN ISSUE NUMBER 1 we presented an introduction to INCREDUCTOR Controllable Inductors and discussed How They Work, Inductance Change Ratio, Signal Winding Q, Temperature Coefficient, Frequency of Operation, Power Handling Capabilities, and the Q Map. Technical data was given for the DB Series on Page 4.

IN THIS ISSUE we continue the discussion. On Page 8 the AQ Series is described. In succeeding issues we will print pages for the AB and DQ Series, and will treat the use of INCREDUCTOR high-frequency saturable reactors in RF switches, panoramic receivers and remotely-tuned broadcast receivers.

HOW TO CHOOSE THE RIGHT INCREDUCTOR UNIT

Controllable inductors are widely used in sweep signal generators, automatic frequency control circuits, antenna matching systems, sweep receivers, remote control operation, telemetering equipment, variable band-width filters, and many other types of equipment.

Units are available for operation from low audio frequency to frequencies over 200 mc. INCREDUCTOR units have also been constructed having signal winding inductances of from a few microhenries up to several hundred henries. Accordingly, in considering any general rules for selection of the best INCREDUCTOR unit, all of the requirements of your application must be kept in mind. For example, controllable inductors operate upon the principle of magnetic saturation of the core material. Thus, if controllable inductors are placed in the vicinity of strong magnetic fields, any variation in the intensity of these fields will influence the inductance of the signal winding. Therefore, if the units are to be used in the presence of magnetic fields, magnetically shielded units should be obtained. If the magnetic fields are intense, special magnetic shielding may be required.

Usually, the frequency of operation should be considered first. The starting frequency (that is, the lowest frequency at which the signal winding circuit is to operate) will indicate the applicable INCREDUCTOR series. Figure 2-1 will enable you to select readily the desired series. For example, if the lowest operating frequency is 3 mc, it will be apparent that the AQ and DQ series should be considered. If the lowest frequency to be used is 10 kc, then it is the DB series. These starting frequency ranges do not represent critical limits, and in many applications satisfactory operation is attained at starting frequencies outside the recommended range.

The information set forth in connection with each of the possible series should then be considered in detail to determine whether the characteristics of those units are suitable in all respects; that is, factors such as the Q, the control current requirements, the inductance change ratio, should all be considered.

If none of our standard units appears to fulfill your particular requirements, we invite you to request an inquiry form and return it to us filled in. We will then recommend the standard unit we think most likely to be suitable for your operation, or quote on the construction of special units custom-made to your exact requirements.

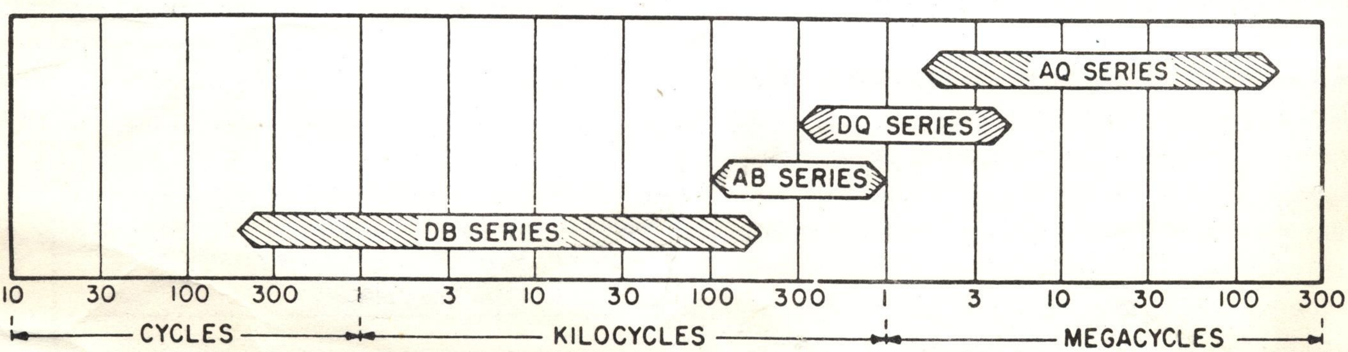

Figure 2-1

Hysteresis and Remanent Magnetism:

Like all magnetic devices, controllable inductors exhibit hysteretic effects. Figure 2-2 shows the variation in inductance of a typical controllable inductor as the control current is varied from zero to its maximum value and back again to zero. In most applications, this hysteretic effect is either of minor importance or may be made to be unimportant by specially designed control circuits. For example, if the controllable inductor is to be used in a sweep oscillator, the sawtooth control current can be used together with means for blanking the oscillator during the return portion of the cycle. Other methods of overcoming hysteretic effects will be discussed below.

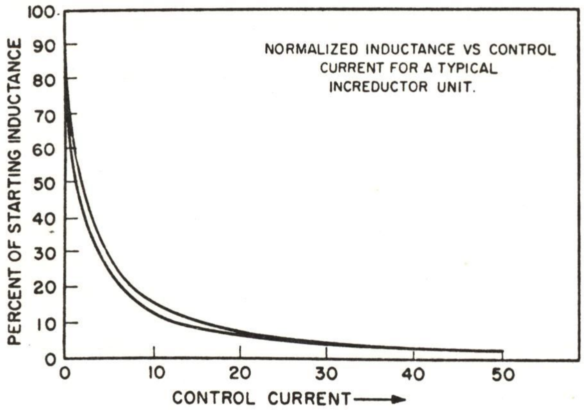

Figure 2-2

Control Circuit Considerations:

In general, it is desirable to design the control circuit so that the polarity of the control current does not change. Thus, if alternating current is to be applied to the control winding, a d-c bias current having magnitude at least equal to one-half the peak value of the alternating current should be provided. One simple means of accomplishing this automatically is to drive the control winding from the plate circuit of a vacuum tube. Generally, pentode tubes are best because their high plate resistance makes the control current correspond to the grid voltage, independently of impedance changes in the control winding. Negative feed back circuits of the current type can be used also to overcome the effects of impedance changes in the control winding. The control current may, of course, be shaped in any desired manner to produce constant rates of change of inductance or frequency. The rate of change of control current is limited only by the self-resonant frequency of the control winding and its associated circuits. When used in suitable circuits, sawtooth control currents of 10 kc or higher can be used.

Usually, higher Q and a better temperature coefficient can be obtained by restricting the operating range of the INCREDUCTOR unit to that actually needed in the particular application. For example, in the frequency range between 5 and 50 mc, it is generally desirable to maintain higher control current levels, thereby improving the Q and obtaining a somewhat lower temperature coefficient.

ABOUT INCREDUCTOR NOTES

This is the second issue of INCREDUCTOR NOTES, a report to be published from time to time to keep you informed of the progress in the development and use of high-frequency electrically-controllable inductors. The series of INCREDUCTOR NOTES will review such factors as temperature characteristics, hysteresis, magnetic bias, frequency range, and Q of the units themselves. There will also be discussions of circuitry developed particularly for use with controllable inductors and typical applications of these devices in commercial and military equipment. Closed-loop circuits for overcoming the effects of hysteresis and temperature changes, circuits for shaping driving currents, sweep generator circuits and many others will be described. We suggest that you collect INCREDUCTOR NOTES in a three-ring loose-leaf binder.

If this copy was mailed to you using an address plate, you will automatically receive future issues. If your address needs correcting, or if a friend would like to receive INCREDUCTOR NOTES, please clip the coupon below.

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Closed-loop Control Circuits:

In applications of controllable inductors for precision control, it is desirable to make use of closed-loop control circuits which eliminate the effects of hysteresis, changes in temperature, and supply voltage variations. One such closed-loop circuit is shown in Figure 2-3. In this example, the signal winding of the INCREDUCTOR unit controls the frequency of operation of an oscillator circuit. The output voltage of the oscillator is integrated by the 100K resistor and the 82 μμf capacitor combination, the resulting signal being rectified by the following diode to produce a d-c control voltage inversely proportional to the oscillator frequency. The oscillator voltage is sampled also by the upper diode and a portion of the resultant direct voltage is then added in series with the integrated signal. The portion to be added is determined by the setting of the slider on the 250K potentiometer. The resultant voltage is amplified and applied to the grid of a control tube that regulates the current through the control windings of the INCREDUCTOR unit. This control current represents an error signal which maintains the oscillator circuit at the frequency determined by the setting of the potentiometer; that is, the adjustment of the potentiometer determines the voltage applied to the grid of the control tube and hence controls the current through the control winding of the INCREDUCTOR unit. Because only one frequency corresponds to each setting of the potentiometer, the closed-loop circuit acts to eliminate the effects of hysteresis and temperature in the controllable inductor and changes in supply voltage on the oscillator circuit.

Our engineers have developed many other closed-loop circuits that permit the use of controllable inductors in precision circuit applications. Their assistance to you in your particular problems is always available.

Bellwether Closed-loop Circuits:

A single closed-loop circuit such as that shown in Figure 2-3 can be used also to control a number of INCREDUCTOR units operating under similar environmental conditions. For example, in a radio receiver where a number of separate stages of tuning must be controlled and in which all are subject to the same conditions so far as temperature and hysteresis are concerned, the control windings of all of the INCREDUCTOR units may be connected in series. If one of these INCREDUCTOR units is connected into a closed-loop circuit, all of the units will follow the controlled one. Our engineers have coined the name "Bellwether" for circuits of this type.

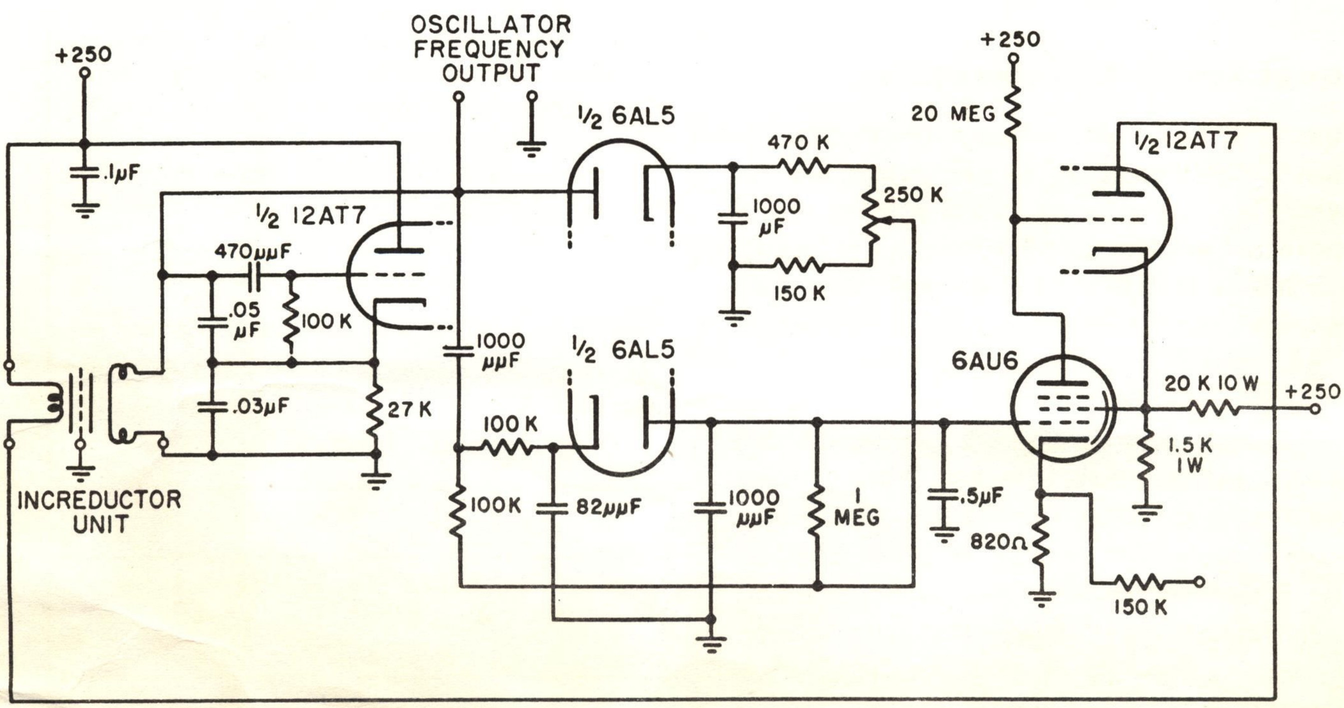


Figure 2-3

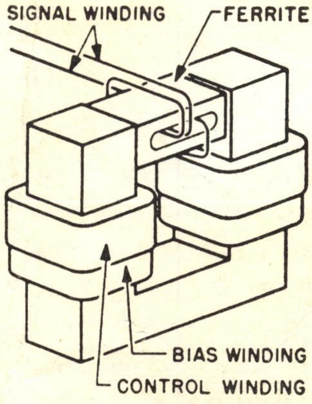
SERIES AQ

The units of this series are particularly useful in the higher frequency ranges between about 1.5 and 200 megacycles. The core configuration, illustrated in the sketch, consists of a U-shaped ferromagnetic yoke carrying the control and bias windings. A slotted ferrite bar bridges the open end of the yoke and carries a balanced signal winding. These units provide a change in inductance of the signal winding of about 3 to 1 at the lower frequencies and 1.5 to 1 at the higher frequencies. By providing a reverse current in the bias winding, significantly greater inductance changes can be attained at the expense of lower starting Q.

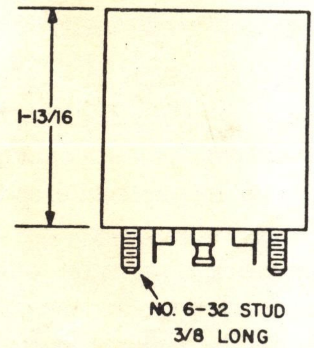
These units require only about one watt of driving power to achieve maximum inductance change.

These INCREDUCTOR units have the greatest temperature stability of any controllable inductor. The maximum coefficient of frequency drift is less than 0.06% per degree C. In circuits where the control current is above about 6 ma, or with residual point operation, the maximum coefficient is less than 0.02%.

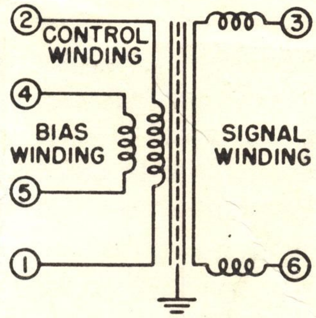
The overall dimensions of these units have been reduced and they are now packaged in hermetically sealed cans of smaller dimensions than earlier units.



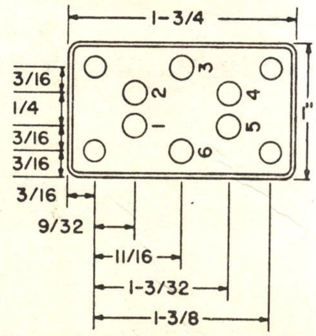
Core Configuration



Exterior Dimensions



Circuit Diagram



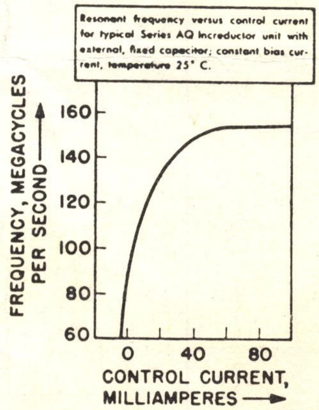
Base Diagram

TYPE	62AQ2	62AQ3	62AQ4	72AQ2	72AQ3	81AQ2
SIGNAL WINDING						
Nominal Maximum Inductance (μh)	20	7.7	4.3	1.2	0.37	·0.10
Minimum Inductance Change Ratio at 70 ma. Control Current: −6.0 ma. Bias Current	6:1	6:1	6:1	5:1	5:1	3:1
Zero Bias Current	3:1	3:1	3:1	2.5:1	2.5:1	1.5:1
Maximum Q	70	70	80	80	80	80
Starting Frequency Range (mc)	1.5–5	2.5–8	3.5–10	7–20	20–60	60–150
Capacity to Electrostatic Shield (μμf)	6	5	4	4	3	3

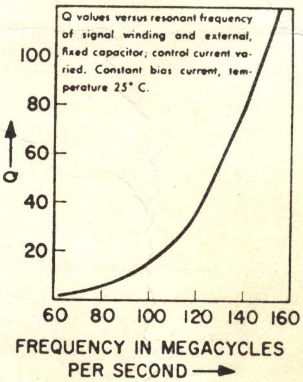
Control Winding—The control windings are identical throughout this series. The nominal inductance is 3.0 henries and the d-c resistance is 200 ohms. The peak current should not exceed 100 ma and the average current should not exceed 70 ma.

Bias Winding—Each unit carries a bias winding to permit maximum flexibility in circuit applications. The nominal inductance is 0.5 henries and the d-c resistance is 200 ohms. A maximum bias current of 6 ma is recommended.

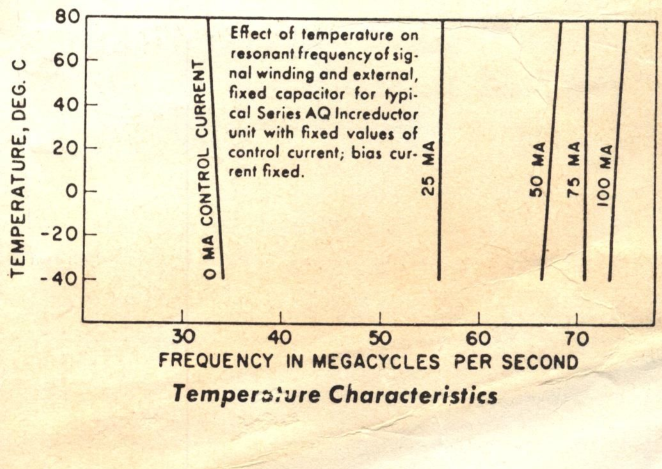
Where it is desired to track a number of INCREDUCTOR units, it is recommended that special precision units be ordered as a group. Such units are specified by adding the suffix "P" to the above designations.



Control Characteristics



Q Characteristics



Temperature Characteristics