SSB–Filters

(PART 4)

This is the fourth article of a series from a training course written by Collins Radio Company for personnel concerned with single sideband communications.

Both SSB transmitters and SSB receivers require very selective bandpass filters in the region of 100 to 500 kilocycles.

In receivers, a high order of adjacent channel rejection is required if channels are to be closely spaced to conserve spectrum space. In SSB transmitters, the signal bandwidth must be limited sharply in order to pass the desired sideband and reject the other sideband. The filter used, therefore, must have very steep skirt characteristics and a flat bandpass characteristic.

These filter requirements are met by LC filters, crystal filters, and mechanical filters.

Crystal Filters

Until recently crystal filters, used in commercial SSB equipments, were in the 100-kilocycle range. Such filters have excellent selectivity and stability characteristics, but their large size makes them subject to shock or vibration deterioration. Also, their cost is quite high.

Newer crystal filters are being developed that have extended frequency range and are smaller. These newer crystal filters are more acceptable for use in SSB equipment.

LC Filters

LC filters have been used at IF frequencies in the region of 20 kilocycles. However, generation of the SSB signal at this frequency requires an additional mixing stage to obtain a transmitting frequency in the high-frequency range. For this reason LC filters are not widely used.

Mechanical Filters

The recent advancements in the development of the mechanical filter have led to its acceptance in SSB equipment. Mechanical filters have excellent rejection characteristics, are extremely rugged, and are small enough to be compatible with miniaturization of equipment. Also to the advantage of the mechanical filter is a Q in the order of 10,000 which is about 100 times the Q obtainable with electrical elements.

Although the commercial use of mechanical filters is relatively new, the basic principles on which they are based is well established.

The mechanical filter is a mechanically resonant device that receives electrical energy, converts it into mechanical vibration, then converts the mechanical energy back into the electrical energy at the output. The mechanical filter consists basically of four elements:

1. An input transducer that converts the electrical input into mechanical oscillations.
2. Metal disks that are mechanically resonant.
3. Coupling rods that couple the metal disks.
4. An output transducer that converts the mechanical oscillations back into electrical oscillations.

Figure 1 shows the elements of the mechanical filter. Figure 2 shows the electrical analogy of the mechanical filter. In the electrical analogy, the series resonant circuits L_1C_1 represent the metal disks, the coupling capacitors C_2 represent the coupling rods, and the input and output resistances R represent the matching mechanical loads.

Transducers

The transducer, which converts electrical energy into mechanical

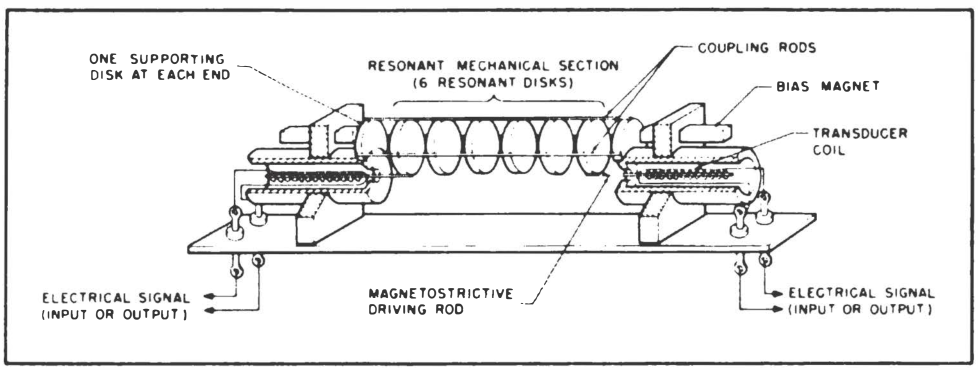
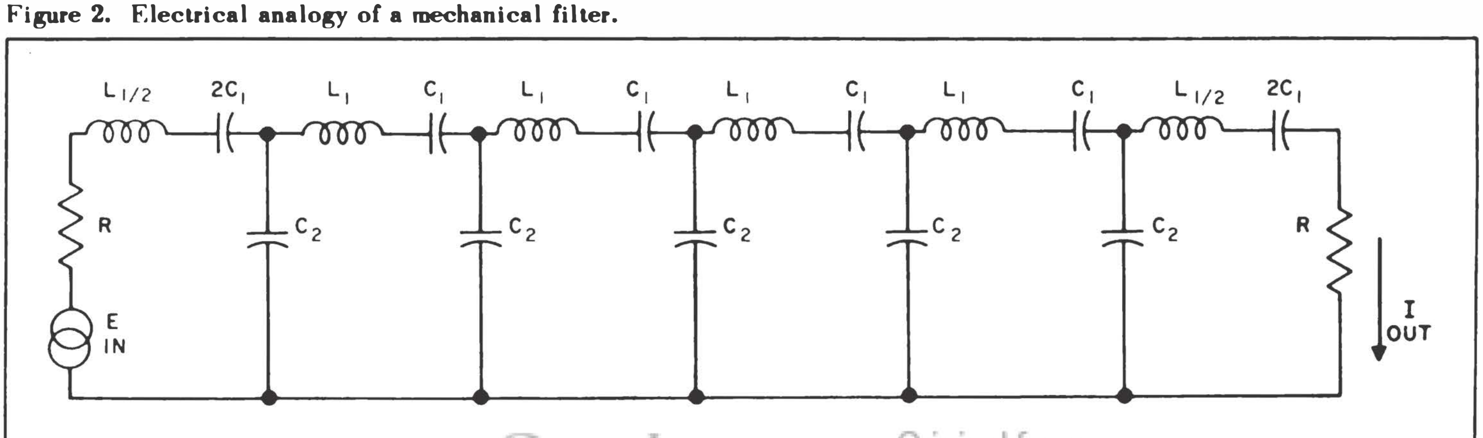


Figure 1. Elements of mechanical filter.

Figure 2. Electrical analogy of a mechanical filter.



energy and vice versa, may be either a magnetostrictive device or an electrostrictive device.

The magnetostrictive transducer is based on the principle that certain materials elongate or shorten when in the presence of a magnetic field. Therefore, if an electrical signal is sent through a coil, which contains the magnetostrictive material as the core, the electrical oscillation will be converted into mechanical oscillation. The mechanical oscillation can then be used to drive the mechanical elements of the filter.

The electrostrictive transducer is based on the principle that certain materials, such as piezoelectric crystals, will compress when subjected to an electric current.

In practice, the magnetostrictive transducer is more commonly used. The transducer not only converts electrical energy into mechanical energy and vice versa; it also provides proper termination for the mechanical network. Both of these functions must be considered in transducer design.

From the electrical equivalent circuit, it is seen that the center frequency of the mechanical filter is determined by the metal disks which represent the series resonant circuit L_1C_1.

Skirt Selectivity

In practice, filters between 50 and 600 kilocycles can be manufactured. This by no means indicates mechanical filter limitations, but is merely the area of design concentration in a relatively new field. Since each disk represents a series resonant circuit, it follows that increasing the number of disks will increase skirt selectivity of the filter.

Skirt selectivity is specified as *shape factor* which is the ratio (bandpass 60 decibels below peak)/(bandpass 6 decibels below peak). Practical manufacturing at present limits the number of disks to eight or nine in a mechanical filter.

A six-disk filter has a shape factor of approximately 2.2; a seven-disk filter, a shape factor of approximately 1.85; a nine-disk filter, a shape factor of approximately 1.5. The future development of mechanical filters will without doubt bring an even faster rate of cutoff.

Coupling

In the equivalent circuit, the coupling capacitors C_2 represent the rods that couple the disks. By varying the mechanical coupling between the disks, that is, by making the coupling rods larger or smaller, the bandwidth of the filter is varied.

Because the bandwidth varies approximately as the total area of the coupling wires, the bandwidth can be increased by using either larger or more coupling rods. Mechanical filters with bandwidths as narrow as 0.5 kilocycle and as wide as 35 kilocycles are practical in the 100- to 500-kilocycle range.

Passband

Although an ideal filter would have a flat "nose" or passband, practical limitations prevent the ideal from being attained. The term "ripple amplitude" or "peak-to-valley ratio" is used to specify the nose characteristic of the filter.

The peak-to-valley ratio is the ratio of maximum to minimum output level across the useful frequency range of the filter (figure 3). A peak-to-valley ratio of 3 decibels can be obtained on a production basis by automatic control of materials and assembly. Mechanical filters with a peak-to-valley ratio of 1 decibel can be produced with accurate adjustment of filter elements.

Spurious responses occur in mechanical filters because of mechanical resonances other than the desired resonance. By proper design, spurious resonances can be kept far enough from the passband to permit other tuned circuits in the system to attenuate the spurious responses.

Other Characteristics

Other mechanical filter characteristics of importance include insertion loss, transmission loss, transfer impedance, input impedance, and output impedance.

Since the input and output transducers of the mechanical filter are inductive, parallel external capacitors must be used to resonate the input and output impedances at the filter frequency. With such capacitors added, the input and output impedances are largely resistive and range between 1,000 ohms and 50,000 ohms.

The insertion loss is measured with both the source and load impedance matched to the input and output impedance of the filter. The value of insertion loss ranges between 2 decibels and 16 decibels, depending on the type of transducer.

The transmission loss is an indication of the filter loss with source and load impedances mismatched. The transmission loss is of importance when using a mechanical filter in pentode IF amplifiers where both source and load impedance are much greater than the filter impedances.

The transfer impedance is useful to determine the overall gain of a pentode amplifier stage that makes use of a mechanical filter. The transfer impedance of the filter multiplied by the transconductance of the pentode gives the gain of the amplifier stage.

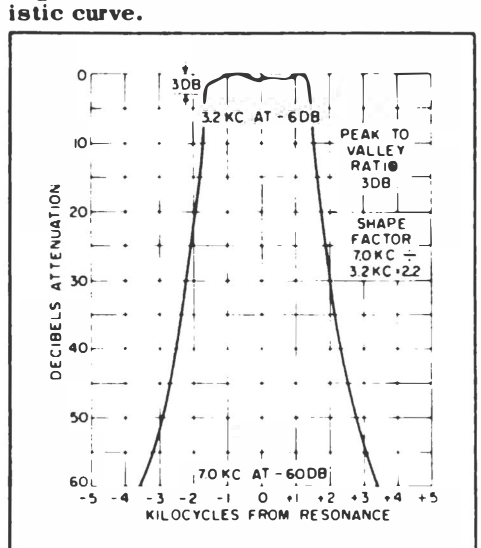
The physical size of the mechanical filter makes it especially useful for modular and miniaturized construction. Recent developments have resulted in a tubular filter that is about ½ inch in diameter by 1¾ inches long.

Types

Types of mechanical filters other than the disk type are being used. One, the plate type, is a series of flat plates assembled in a ladder arrangement.

Another type that has recently

Figure 3. Mechanical filter characteristic curve.



been developed is the neck-and-slug type. This type of filter consists of a long cylinder that is turned down to form the necks that couple the remaining slugs.

All mechanical filters are similar in that they have mechanical resonance. They differ in that they have various modes of mechanical oscillation to gain their purpose. They may also have different types of transducers.

The next subject to be taken up by the series on SSB communication systems is exciters.

Operating Controls and Terminals of a Basic Oscilloscope

The following reference symbols are shown in the accompanying schematic diagram of a basic oscilloscope:

Name of Control	Reference Symbol	Function
Vertical position	R3	Changes the d.c. potential of the vertical-deflection plate, and thus controls the vertical position of the trace.
Horizontal position	R4	Changes the d.c. potential of the horizontal-deflection plate, and thus controls the horizontal position of the trace.
Intensity	R1	Changes the voltage of the grid of the cathode-ray tube, and thus controls the intensity of the trace.
Focus	R2	Changes the voltage of the focusing electrode of the cathode-ray tube, and thus adjusts the focal point of the beam.
Vertical gain	R5	Changes the voltage of the input signal applied to the grid of the vertical amplifier, thus controlling the amplitude of the vertical signal.
Horizontal gain	R6	Changes the voltage of the input signal applied to the grid of the horizontal amplifier, thus controlling the amplitude of the horizontal signal. (Input signal is produced by the time-base generator or by an external signal source.)
Coarse frequency	S4	Selects the various sweep capacitors. This switch provides a rough adjustment of the sawtooth oscillator frequency.
Fine frequency	R7	Provides a fine adjustment of the sweep frequency by controlling the rate at which the selected sweep capacitor is charged.
Sync. amp.	R8	Varies the amplitude of the synchronizing voltage applied to the time-base generator, thus enabling the operator to "lock-in" the signal being viewed.
Sync. selector	S3	Provides a means for the operator to select a synchronizing signal from either an internal or an external source.
Vertical input	T1	Provides a terminal for the connection of an external signal source to the vertical amplifier.
Horizontal input	T2	Provides a terminal for the connection of an external signal source to the horizontal amplifier.
Test signal	T3	Provides a voltage of stated amplitude for testing amplifier sensitivity.
Ext. sync.	T4	Provides a terminal for connecting the external synchronizing-signal source.
Ground	T5 T6	These binding posts are used to ground the chassis of the oscilloscope to the ground of any input signal source.
Horizontal input selector	S2	Allows either an external signal or the internally generated sawtooth sweep signal to be applied to the horizontal-amplifier grid.