Resistor-contro[illegible] LC network drives tunable discriminator

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A single potentiometer can adjust the fixed-tuned circuits that determine the mark-and-space frequencies in an audio-frequency-shift-keyed discriminator. This can be accomplished if the potentiometer controls the feedback current that passes through the inductor of each LC combination. Such calibrated single-control tuning is an advantage when reception of any one pair of several widely used shifts is necessary, because the mark-and-space filters do not have to be individually and repeatedly set by a frequency counter or by some other instrument.

A LaPlace analysis of a current-driven tuned circuit will show the dependence of the resonant frequency on the amount of feedback. The tuned circuit in Fig. 1 has a transfer function that is:

$$A(s) = \frac{s + R_L}{s^2 + R_L s + 1}$$

Feedback provided by the second amplifier is:

$$B(s) = \frac{K}{s^2 + R_L s + 1}$$

where K is the amplifier gain, a function of the potentiometer setting, and may be positive or negative in value. The complete transfer function becomes:

$$H(s) = \frac{s + R_L}{s^2 + R_L s + 1 - K}$$

The denominator of this equation, which is of major importance in this analysis, is of the form:

$$s^2 + (AQ)s + \omega^2$$

where A is a constant, Q is the circuit's selectivity or quality factor, and ω is the radian frequency of the circuit. Thus it is observed that $\omega = (1-K)^{1/2}$. This assumes that bandwidth and gain of the circuit are independent variables.

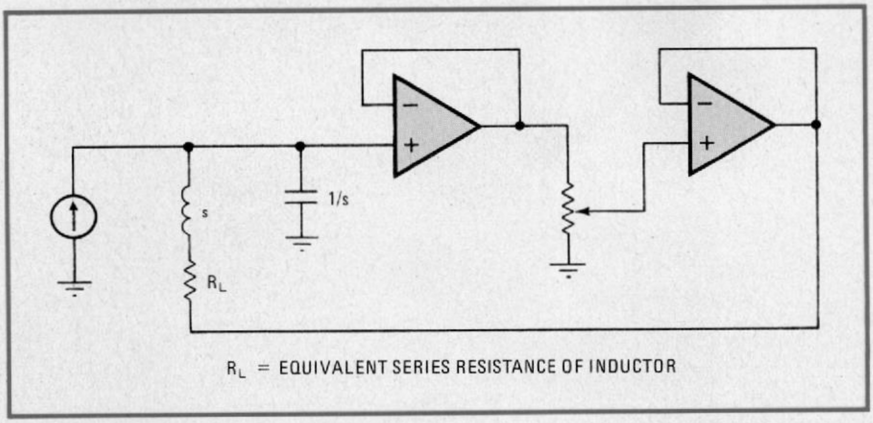
Analysis of the feedback loop containing a tuned circuit that is driven from a voltage source is somewhat more complicated, but the results are similar. For the actual voltage-driver circuit in Fig. 2, the transfer function is approximately:

$$H(s) = \frac{(s + R_L)}{R_4[s^2 + s(R_L + {}^1/R_4 + {}^1/R_5) + 1 \pm K]}$$

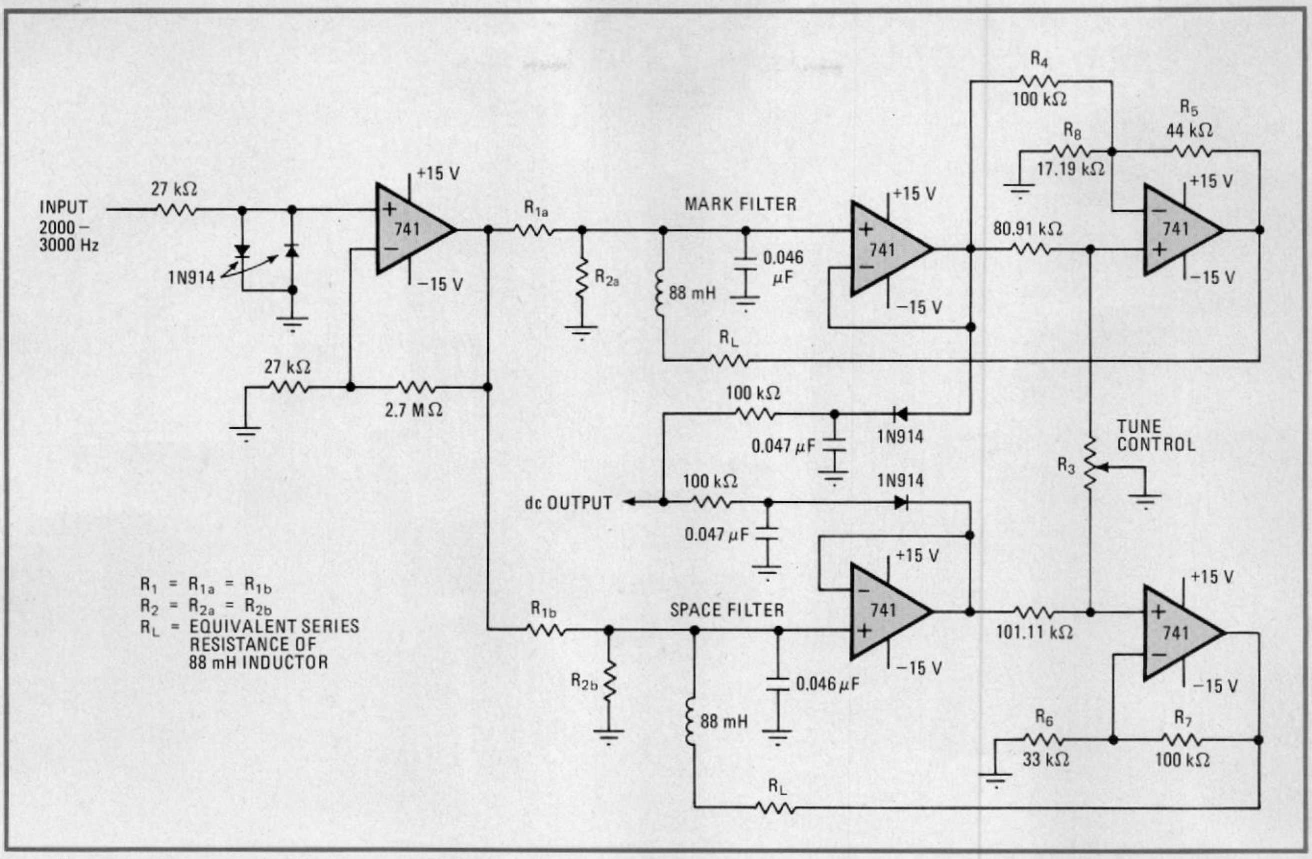
where the radian frequency term is the same, but the value of Q depends largely on resistors R_1 and R_2, and the value of K is dependent on R_3.

Determination of R_1, R_2, and R_3 is most important for circuit optimization of Q and transient response. After limiting of the 2-to-3-kilohertz input signal by the first operational amplifier, the 14-volt output signal must be reduced by one half by the voltage divider consisting of R_1 and R_2. This will prevent overdrive of subsequent stages containing two identical tuned circuits with equivalent impedance Z_x. In addition, the dc output of the circuit is a function of the relationship of the mark-and-space frequency to the frequency of each tuned circuit (and thus Z_x, R_1, and R_2).

An unloaded (no-feedback) Q of about 100 is to be expected at 2,500 Hz from each resonant circuit, providing a Z_x of 138,200 ohms. It is reasonable to set a loaded Q of 25, providing a bandwidth of 100 Hz. Resistor R_2 is selected for a Q of 50 so that the parallel equivalent of Z_x, R_1, and R_2 reduces the Q to 25 and



1. Current analysis. Resonant frequency of tuned circuit is affected not only by L and C values but also by magnitude of feedback current through inductor. Potentiometer may control gain of amplifier and thus resonant frequency. Circuit is simpler to analyze but yields results similar to voltage-driven discriminator network described in text.



2. A discriminating network. Resistor-tuned filters provide one-control adjustment of mark-and-space frequencies. Shifts are continuously adjustable from zero to 1 kilohertz at a center frequency of 2,500 hertz and are linearly proportional to potentiometer setting.

RESISTOR-TUNED DISCRIMINATOR

POT ROTATION	FREQUENCY (Hz)	
(%)	MARK	SPACE
0	2,500	2,500
10	2,549	2,451
20	2,598	2,401
30	2,647	2,352
40	2,697	2,302
50	2,747	2,252
60	2,797	2,202
70	2,847	2,152
80	2,897	2,102
90	2,949	2,051
100	3,000	2,000

yields the desired voltage division. Thus, R_2 is equal to 138,200 Ω, and R_1 is equal to the parallel combination of Z_x and R_2, or 69,100 Ω.

The resonant frequency of the mark-and-space filters is directly determined by R_3. With the potentiometer's resistance at a minimum as measured from the junction of the 101-kilohm resistor and the noninverting input of the 741 op amp, the noninverting gain for the mark filter is 0.44, which nullifies the inverting gain of 0.44 from the following amplifier stage. Thus the mark resonant frequency remains at 2,500 Hz. Feedback through the space resonant circuit is zero, and it is also resonant at 2,500 Hz. When R_3 increases, the inverting gain for the mark filter becomes greater than the noninverting gain and the mark resonant frequency increases. The feedback signal through the space resonant circuit decreases the space resonant frequency. The maximum input signal available across R_3 is 0.09 times the output signal; at this setting the op amp gain is 4. The lowest resonant frequency is thus $(1 - 0.36)^{1/2}$ (2,500) = 2,000 Hz. Conversely, the mark filter has a maximum frequency of $(1 + 0.44)^{1/2}$ (2,500) = 3,000 Hz.

The table shows the relationship of the potentiometer setting to the mark-and-set frequency pairs. The resonant frequency of the mark filters should be trimmed to a center frequency of 2,500 Hz by R_8. The space filter's lower limit should be trimmed by R_6 or R_7; the mark filter's upper limit should be set by R_4 or R_5.

The dc output is derived from intermediate op amps in conjunction with half-wave rectifier networks. The output voltage will always be positive for received mark frequencies and negative for space frequencies, permitting a suitable source for transistors that will drive radio teleprinter relays and similar equipment. Rejection of off-frequency mark-or-space signals is excellent. Mark-and-space frequency pairs can be within 100 Hz of each other while still providing good circuit performance. ☐

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