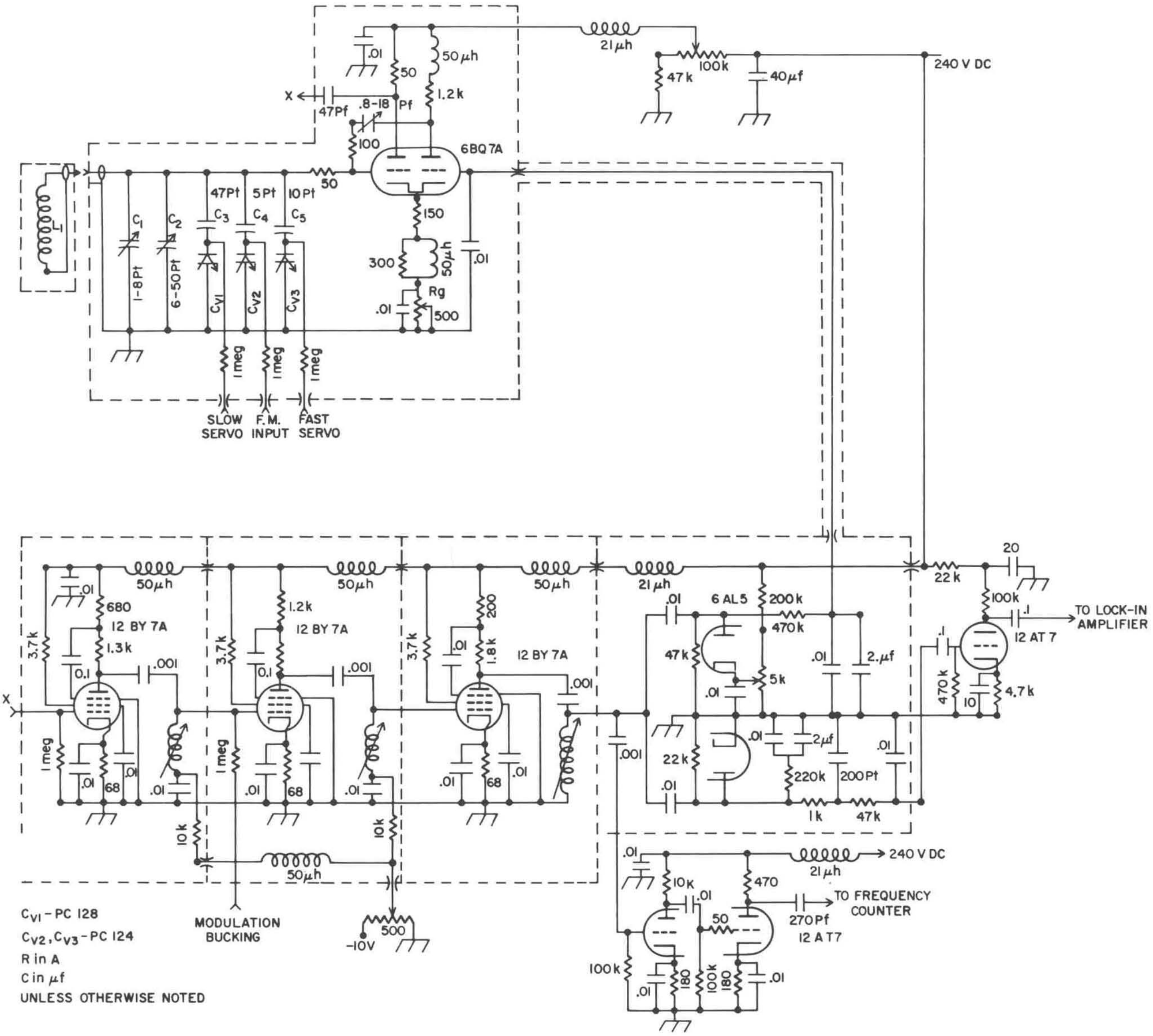

FIGURE 2. *Oscillator detector circuit.*

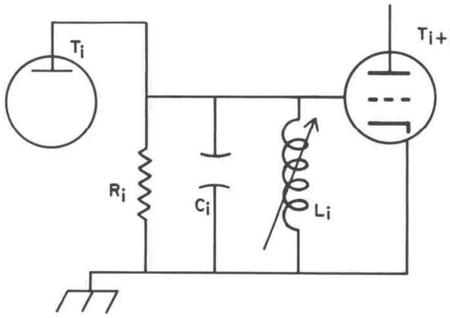

FIGURE 3. *A-C equivalent circuit of a typical stage in rf amplifier.*

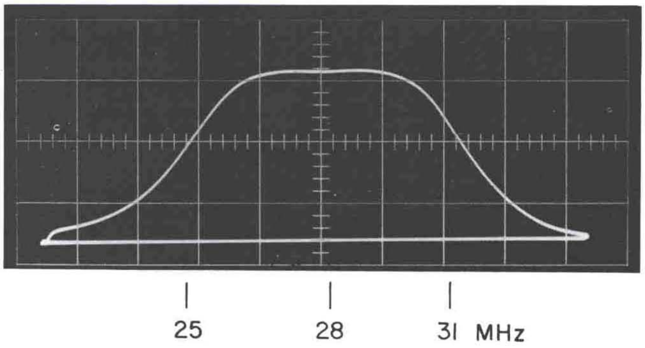

FIGURE 4. *Oscilliscope trace of the band pass of the rf amplifier.*

overall gain at any frequency, f, is the product of the individual stage gains at that frequency. The stage gain is given by

$$G_i(f) = g_{mi} Z_i(f)$$

where $Z_i(f)$ is the impedance function for a single stage. Because of this multiplicative property, if one of the stages has its g_{mi} reduced but its selectivity characteristic, which is determined by $Z_i(f)$, left unchanged, the overall gain is reduced in proportion, whereas the overall selectivity curve is completely unaffected. Consequently, to the extent to which tube capacities and loading do not vary with g_m, it is possible to gain control a stagger-tuned amplifier in any stage or combination of stages [12]. In our case this is accomplished by adjusting the grid voltage on the first two stages.

Following the r-f amplifier the signal is branched; one branch going to a buffer amplifier followed by an electronic frequency counter [13]; the other branch going to the diode detector. The detected signal is then fed into a lock-in amplifier whose output appears as the first derivative of an absorption curve. This is then used to provide the error signal for a servo mechanism which locks the oscillator frequency to the center of the resonance line.

The servo control system is similar to that described by Volpicelli et al. [7] and utilizes two control loops. The fast loop, which responds directly to the error signal and provides a quick response to short-term fluctuations, has a range up to 2 KHz. The second loop has a much slower response and utilizes a commercially available servo amplifier [14] and motor. Tachometer feedback is used and the motor is coupled to a 10-turn potentiometer via a gear box and antibacklash gears giving a total reduction ratio of 1000:1. By coupling the potentiometer shaft to the gear train with a dual magnetic clutch it is also possible to manually adjust the voltage on VCD1 and hence the oscillator frequency, or with the aid of a second motor and gear drive, sweep the frequency. The ability to manually adjust the oscillator frequency greatly facilitates the initial locking of the servo system to the center of the resonance line.

Frequency modulation is provided by varying the voltage on VCD2 at the modulation frequency. As a result of the change in capacity in the tuned circuit the quality factor is also modulated which in turn leads to a modulation of the oscillation level. The result of this incidental amplitude modulation causes a signal to appear at the lock-in detector. The resulting shift in the base line of the NQR signal must be eliminated in order that the lock is at the true center of the resonance line. One method of eliminating this undesirable signal is to introduce a signal of equal amplitude and opposite phase at some convenient point before the input of the lock-in amplifier.

The adjustment of this bucking signal is perhaps the most important one of all and should be checked carefully both above and below the resonance frequency before recording data. Since the oscillator frequency is changing as the NQR signal is tracked, the relative capacity of the tank circuit is also changing which means the bucking signal must be adjusted at each datum point to assure that the measurement is being made at the line center. When the r-f level is relatively high the change in level resulting from a change in frequency is quite small, since the feedback is small, and in this case it is possible to adjust the bucking voltage and phase to produce a relatively stable base line. At low r-f levels, where the feedback is large, the oscillator is most sensitive to the shunt impedance and changes in the relative capacity tend to cause base line drift. Hence the operating point must be such that the r-f level is large enough to ensure a stable base line over a frequency range comparable to the line width and yet small enough to avoid saturation of the nuclear resonance.

In the case of $KClO_3$ we were able to select an operating point which gave the maximum signal-to-noise ratio and, with proper adjustment of the bucking voltage, a stable base line over the line width. In order to carry out the adjustment on the bucking signal it was necessary to unlock the spectrometer and manually shift the frequency, by adjusting the voltage on VCD1, to points on both sides of the resonance. Proper adjustment of the bucking voltage, as evidenced by the output of the lock-in detector, showed no noticeable change in the error voltage at points slightly above and slightly below resonance. The servo is then relocked to the center of the resonance and data recorded.

3. System Performance

The NQR spectrometer described in this paper was designed around the ^{35}Cl resonance in $KClO_3$. As previously mentioned the operating frequency is 28 MHz. The servo system used here to track the NQR signal has a range of about 2.0 MHz. The magnitude of the tracking range is related to the change in capacity of the varicap VCD2, the coupling capacitor C_3, the amplifier bandwidth, and the frequency of operation. If ΔC is the effective change in capacity of the tank circuit, f_0 is the operating frequency, and C_0 is the total tank circuit capacity associated with f_0, then the frequency range is given by $\frac{\Delta f}{f} = \frac{1}{2}\frac{\Delta C}{C_0}$ where the magnitude of ΔC is given by $\Delta C = \frac{\Delta C_v}{(1+C_v/C_3)^2}$. Since C_v and ΔC_v are fixed properties of the varicap and since ΔC_v depends only on the range of bias voltage, Δf will be larger at the higher frequencies. In the case where $C_v/C_3 << 1$ and $C' < C_v$, where C' is the parallel tank circuit capacity excluding C_v and C_3, nearly all of the current passing through L will pass through C_v. This, coupled with the fact that the r-f voltage across both L and C_v is nearly equal, causes the varicap to be the principle frequency controlling element. In addition, the major circuit losses occur in L and C_v and the varicap Q becomes very important in determining the overall circuit Q. This becomes important at the higher frequencies. At the lower frequencies C' is larger than C_v and the varicap Q becomes less important.

Some care should be given to the selection of C_3. If C_3 is large compared to C_v and the resonance line is narrow, small error signals applied to C_v may result in frequency corrections larger than the line width thus causing the