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Available sources of antineutrinos exert macroscopic forces on such crystals as a result of elastic scattering. In this paper a chopper is described for modulating the antineutrino forces, in order to excite normal modes of elastic solids. Experiments are reported.

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Chopper for Neutrinos and Antineutrinos

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Abstract

A new approach to weak interaction physics employs detectors which are nearly perfect single crystals, with high Debye temperatures. Total scattering cross sections are proportional to the square of the total number of quarks.

Available sources of antineutrinos exert macroscopic forces on such crystals as a result of elastic scattering. In this paper a chopper is described for modulating the antineutrino forces, in order to excite normal modes of elastic solids. Experiments are reported.

Introduction

Theory has been presented for coherent elastic scattering of very weakly interacting particles by quarks in nearly perfect ^{1,2} single crystals. Elastic scattering experiments were described², employing a torsion balance. An antineutrino source was cycled between small and large distances from the torsion balance. Repulsive forces were observed, consistent with large elastic scattering cross sections, proportional to the square of the number of quarks.

A torsion balance has a long period and responds to seismic vibrations. A harmonic oscillator with much shorter period may be employed, together with an antineutrino chopper, to modulate the incident particle flux at the frequency of the oscillator.

Fork Harmonic Oscillator

An aluminum tuning fork with normal mode frequency close to 87 hertz was employed, as shown in Figure 1. Lead zirconate titanate crystals provided electromagnetic coupling of the normal mode vibrations to a low noise amplifier. Theory predicts the equivalent circuit shown in Figure 2 for the spectral region near the normal mode frequency. Measured values of the parameters are given.

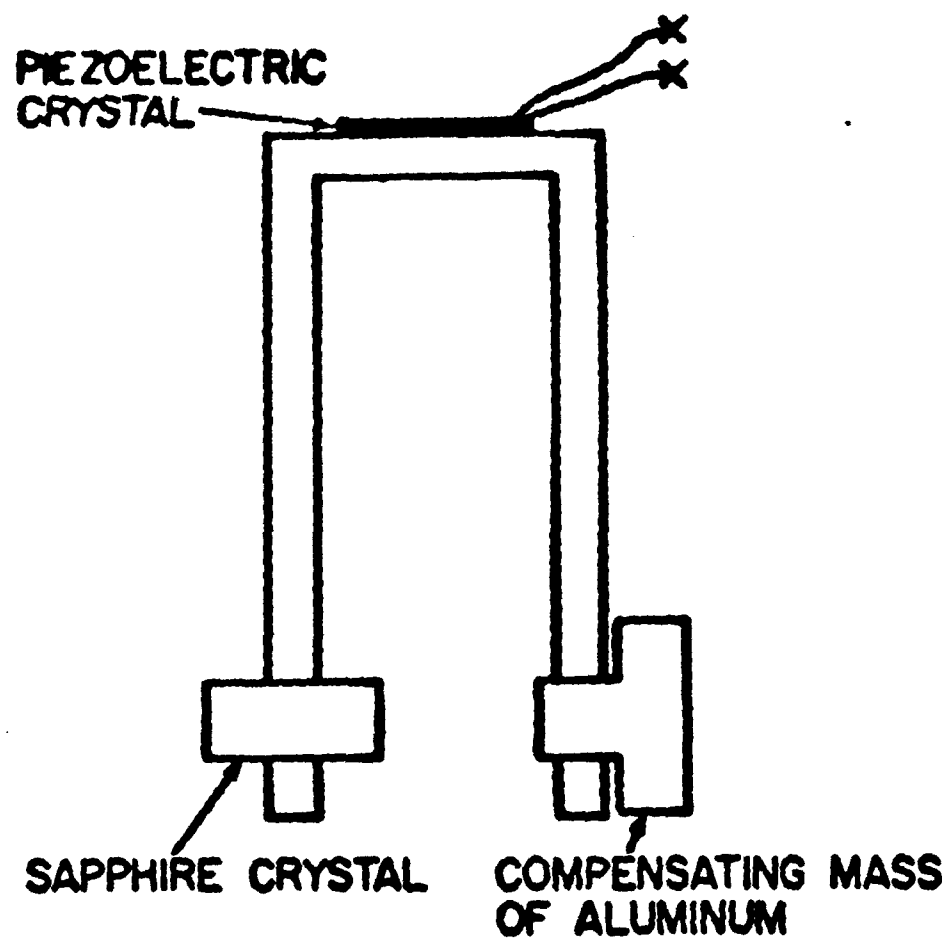
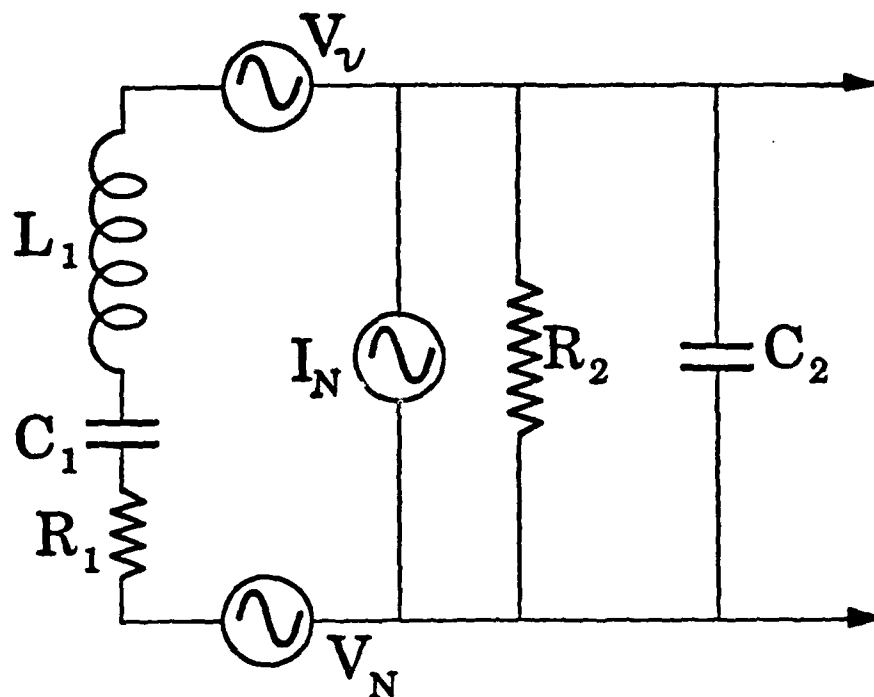


Figure 1



$$L_1 = 1.06 \times 10^5 \text{ HENRIES}$$

$$C_1 = 31.5 \times 10^{-12} \text{ FARADS}$$

$$R_1 = 9361 \text{ OHMS}$$

$$C_2 = 1.2 \times 10^{-7} \text{ FARADS}$$

$$R_2 = 1.9 \times 10^6 \text{ OHMS}$$

$$\langle V_N^2 \rangle = 2kTR_1 \Delta \omega / \pi$$

$$\langle I_N^2 \rangle = 2kT \Delta \omega / \pi R_2$$

$$V_v = K\Phi f(N_T, Z_T, E_v, M, T_0)$$

Figure 2

Chopper System

Three sapphire crystals, each 5 cms in diameter and 7.5 cms long, were mounted at 120 degree intervals between two circular aluminum discs. The crystal structure was rotated at $1/3$ the fork normal mode frequency by a closed loop servosystem. The servosystem was designed to operate with time dependent potentials, with Fourier components far from the 87 hertz fork frequency, in order to avoid large control potentials at the fork normal mode frequency. A synthesizer was preset to a frequency N times the fork frequency. This serves as the reference. A circular disc with $3N$ alternate black and silver radial divisions was mounted on the rotating structure. An infrared source and sensor measured the rotation frequency of the crystals. This was compared with the frequency of the synthesizer. If the speed was too small, the servoamplifier increased power to the d.c. drive motor. If the speed was too large, the servosystem decreased the motor input power.

A second circular disc with 3 silver and 3 black sectors was mounted on the opposite side of the crystal structure. Another infrared source and sensor provided the required reference signal for synchronous detection of the fork output.

A second chopper was developed with six crystals and rotation frequency $1/6$ of the fork normal mode frequency, with another servosystem to control the frequency of rotation to required tolerances.

The system was configured as shown in Figure 3

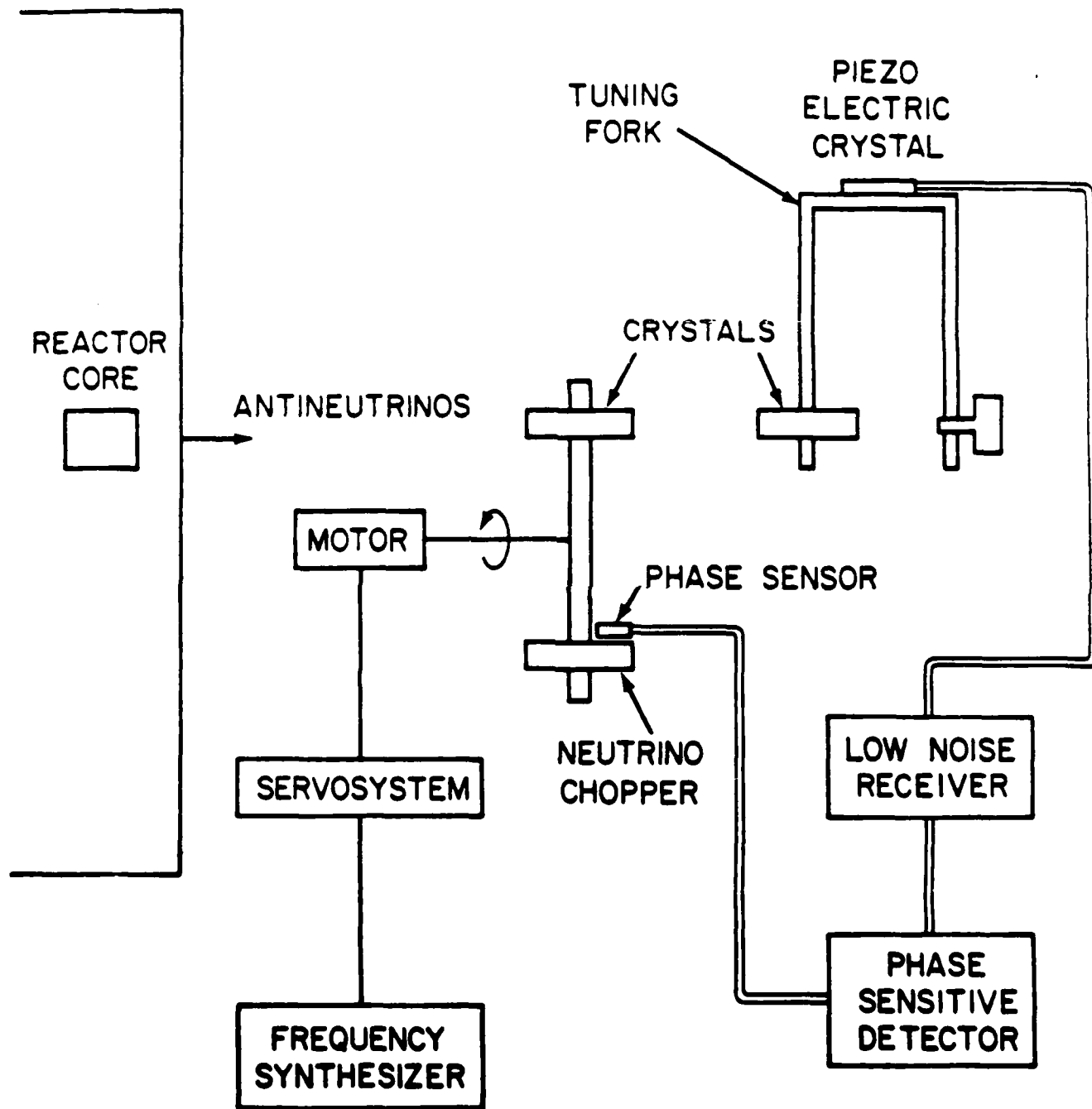


Figure 3

Circuits and Electronics

Figure 4 is the low noise pre amplifier circuit for the tuning fork. This is followed by a postamplifier and synchronous detector of conventional design.

Figure 5 is the circuit diagram of the servo amplifier which controls the chopper frequency.

Observations

The fork chopper system was operated at the United States National Bureau of Standards reactor. With reactor operating at 15 megawatts, a large output was observed, with fork chopper system 20 feet from the core center. When the reactor was switched off, the output of the fork did not immediately fall to a low value, but slowly decreased to 2 1/2 percent of the reactor on value, with a time scale of hours. This is consistent with the conclusion that antineutrinos from Beta decay products were being observed. The neutron and gamma ray backgrounds in the reactor vicinity became very small as soon as the reactor was switched off. Only the antineutrino output, controlled by the long period Beta decays, requires time scales of hours for decay.

To further check the hypothesis that antineutrinos were being observed, different kinds of scatterers were placed between chopper fork system and reactor.

Figure 6 shows a record of power with and without a large single crystal of silicon, placed in the line of sight between reactor and fork chopper. Smaller effects were observed with a large sapphire crystal. Sapphire has a Debye temperature of 1000 kelvin, while silicon has a Debye

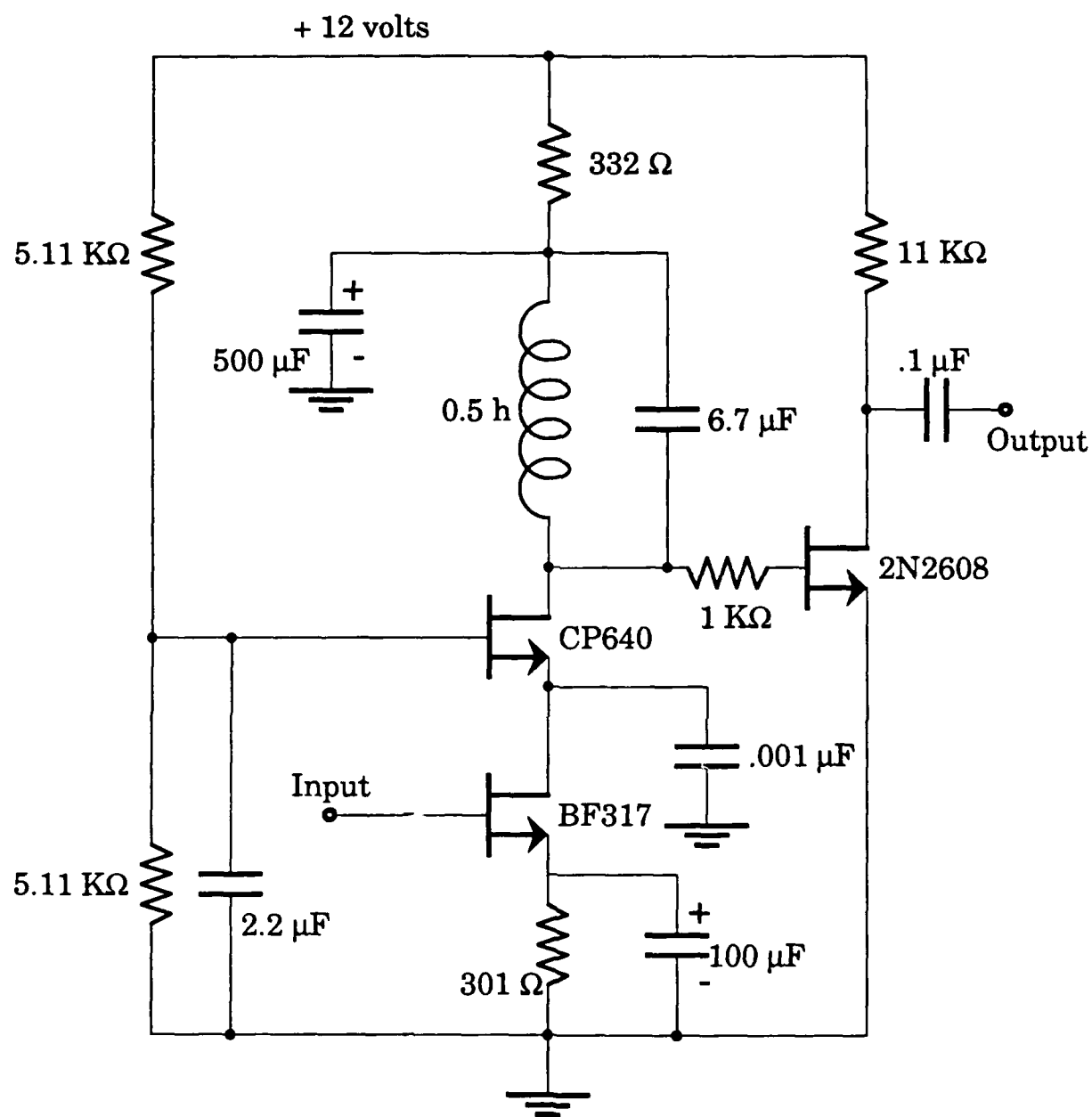
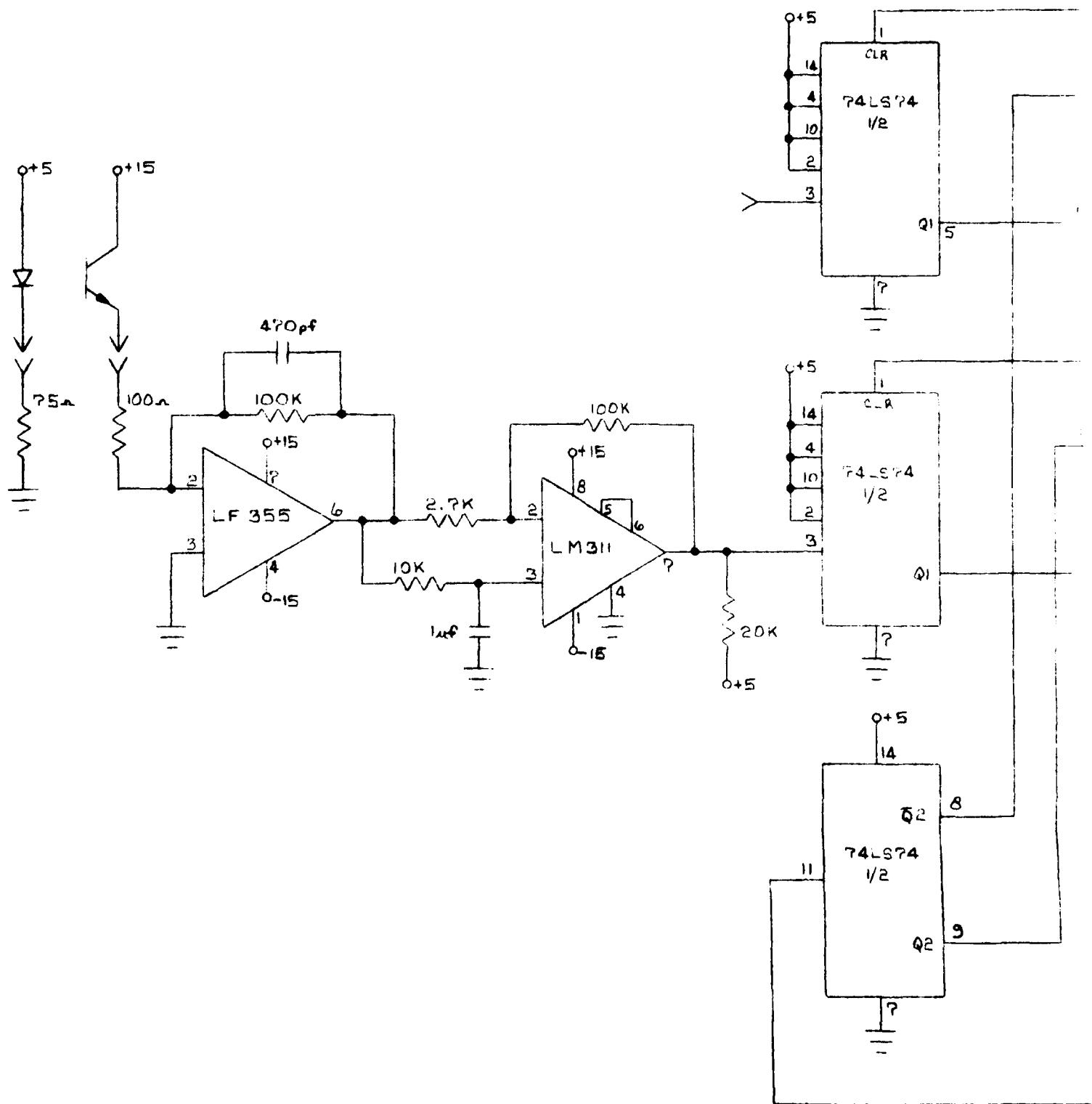
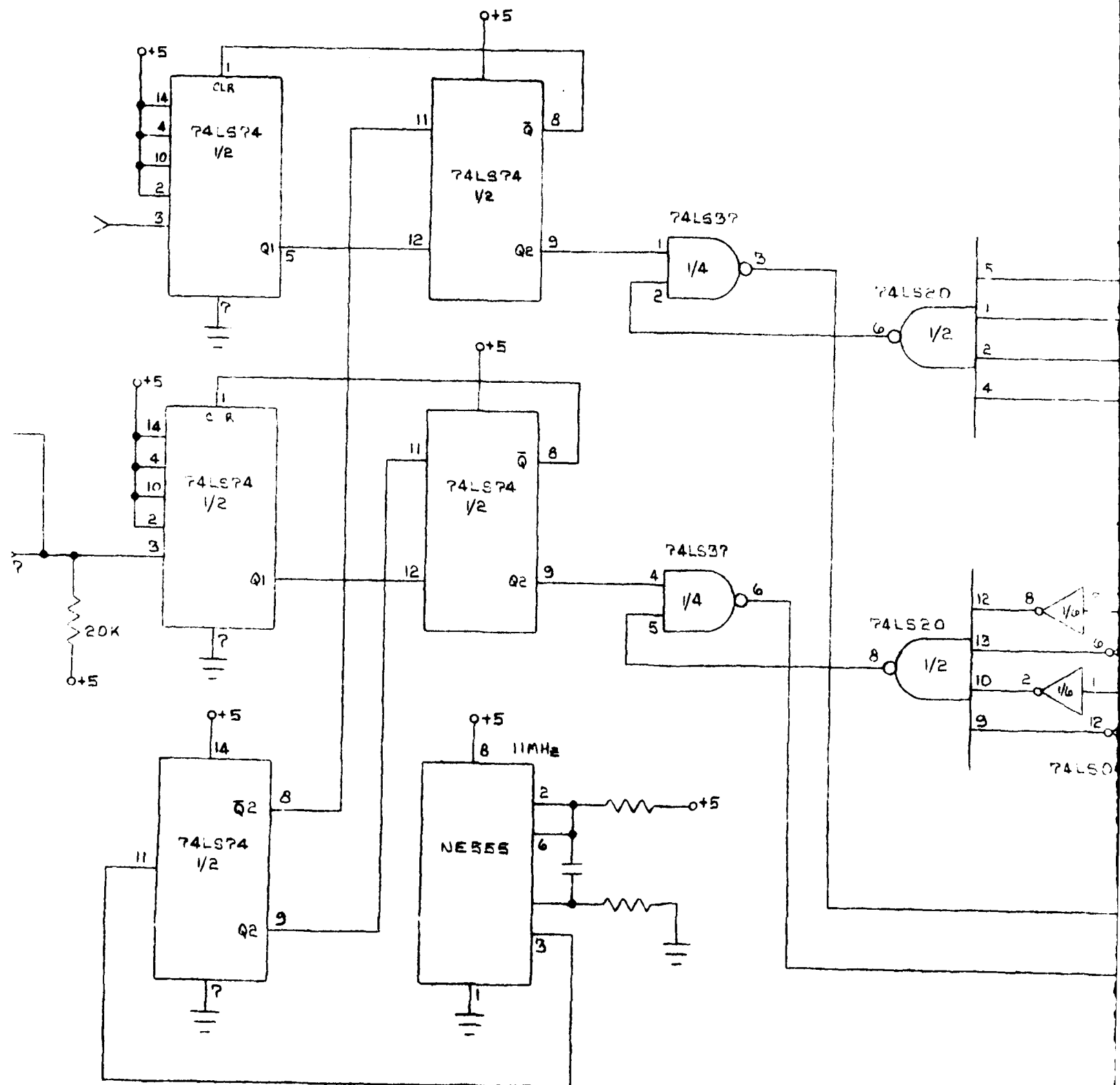
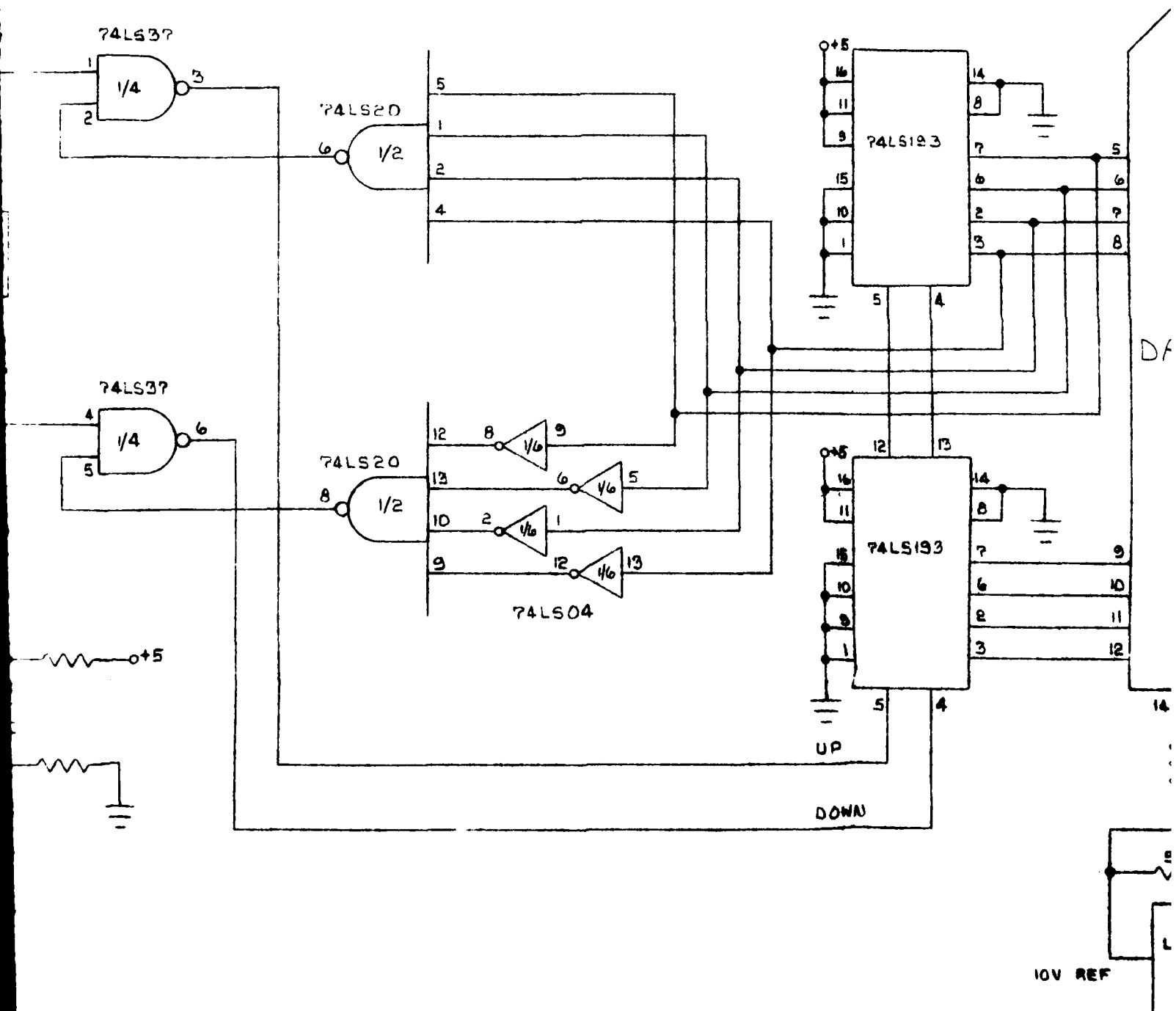
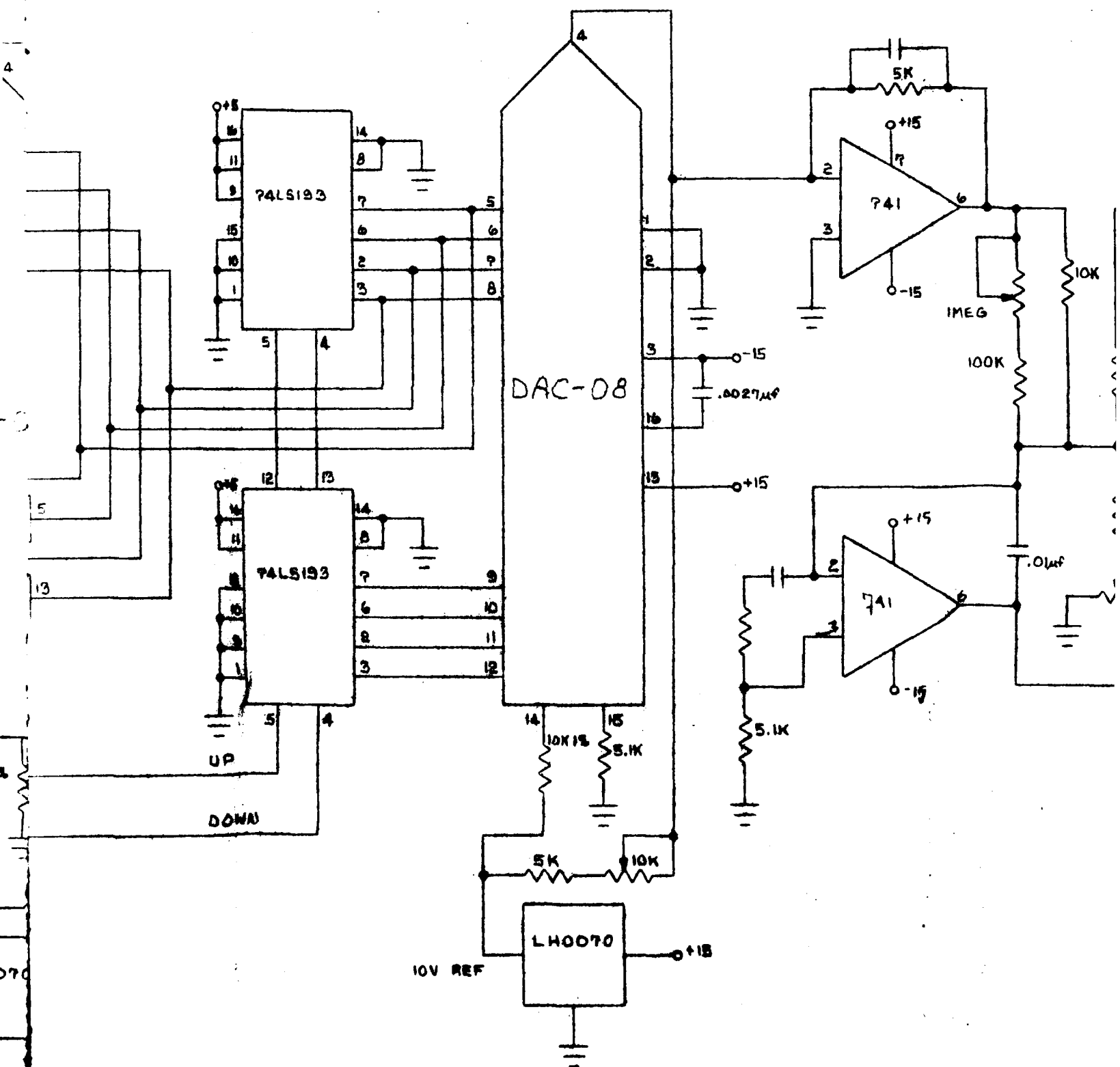


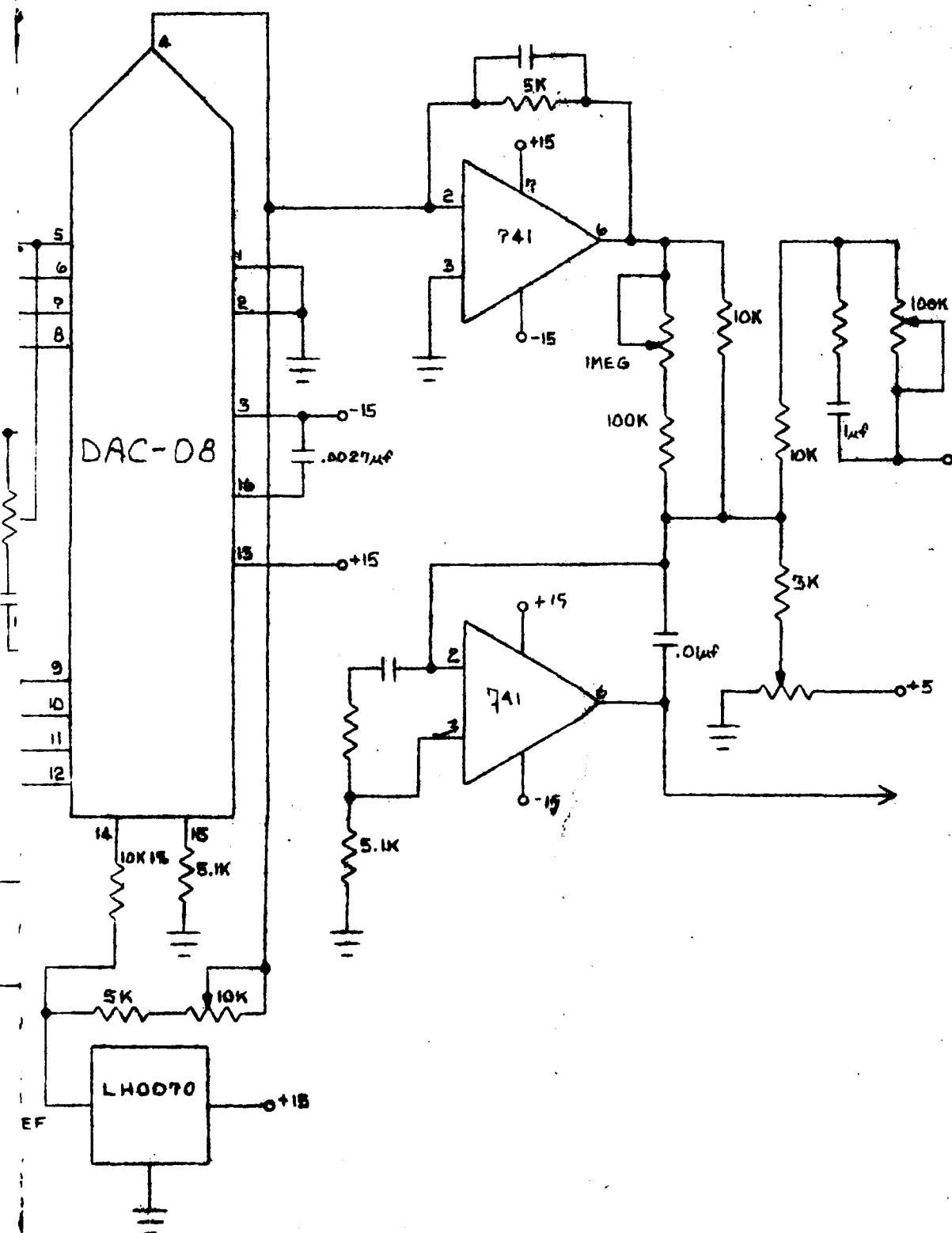
Figure 4

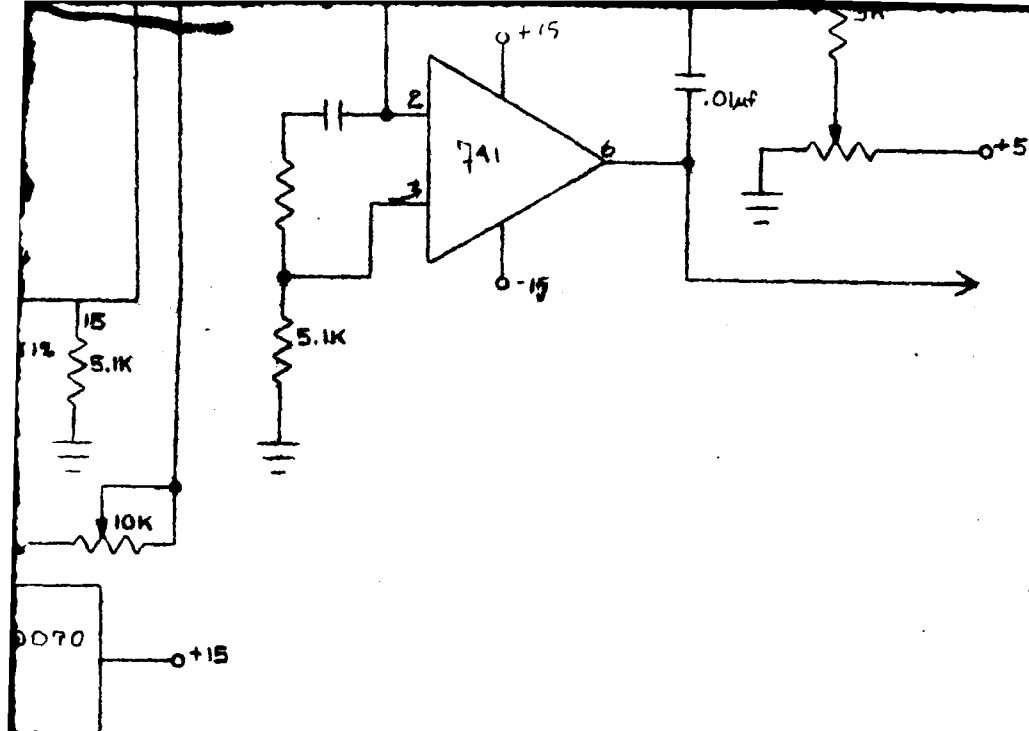












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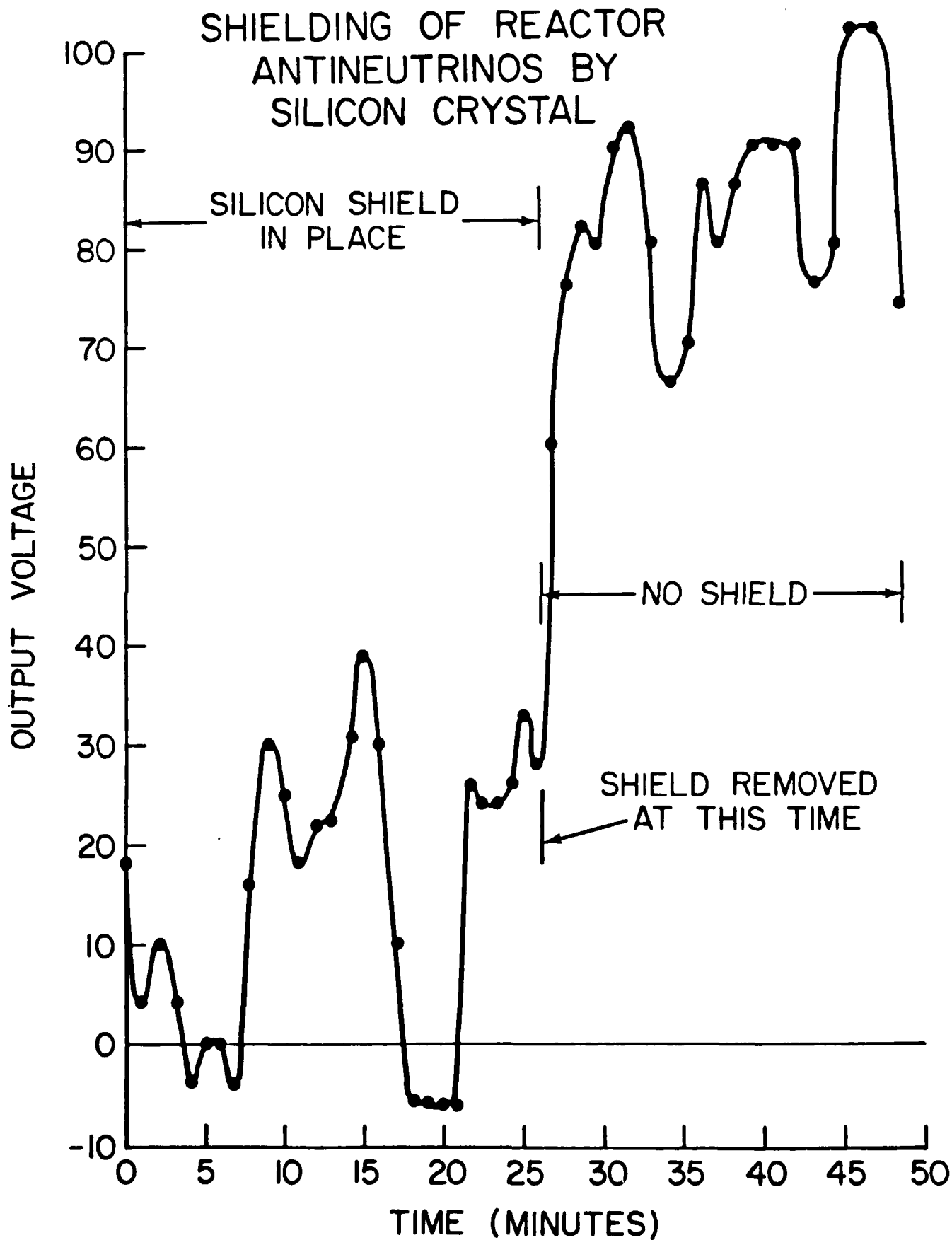


Figure 6

temperature of 645 kelvin. If both crystals were free of dislocations, the sapphire would produce a larger effect than the silicon. We discussed this issue with Dr. R. DesLattes, an x-ray crystallographer at the U.S. National Bureau of Standards. Dr. DesLattes informed us that the large single sapphire crystal has large numbers of dislocations, approximately 100,000 per square centimeter. The silicon crystal has a much smaller number of dislocations and is therefore a superior scatterer for reactor antineutrinos with average energy 1.6 MeV. No significant reductions in fork output were observed when large polycrystalline materials such as lead or aluminum were placed between chopper fork system and reactor. No significant reduction in fork output was observed when powdered sapphire (aluminum oxide crystals) were placed between reactor and chopper fork systems.

All of these experiments were repeated when the reactor was switched off and sufficiently long time elapsed for Beta decay emission to decrease to background levels. No significant effects were observed with reactor off.

Observed Force with Reactor on.

The fork is a harmonic oscillator with mass m , mechanical resistance r and force constant k . The differential equation of motion is

$$m \frac{d^2 x}{dt^2} + r \frac{dx}{dt} + kx = F$$

At resonance, $m \frac{d^2 x}{dt^2} = -kx$ and

$$r \frac{dx}{dt} = i\omega r x = F$$

for harmonic fields.

With reactor off, $F \rightarrow 0$, thermal, electronics, and seismic fluctuations imply a background temperature T_m given in terms of the displacement fluctuations by

$$\frac{1}{2} m \omega^2 \langle x^2 \rangle = \frac{1}{2} k T_m$$

Combining these equations gives fluctuations $\langle F_n^2 \rangle$,

$$\langle F_n^2 \rangle = \kappa^2 \omega^2 \langle x^2 \rangle = \frac{\kappa^2 k T_m}{m}$$

T_m is measured by observing the effect of a noise current generator coupled to the receiver input. Suppose switching the reactor on increases the power by a factor K_r . Then the reactor induced force F_r is given by

$$\langle F_r^2 \rangle = \frac{\kappa^2 k K_r T_m}{m}$$

For these experiments T_m was 55,000 K and $F_r = 3.2 \pm 1 \times 10^{-5}$ dynes.

1. J. Weber Phys. Rev C 31, 1468 April 15, 1985
2. J. Weber Phys. Rev D 38, 1, pages 32-39, July 1, 1988.