CHAPTER III

MEASUREMENT AND APPARATUS

3.1 The Measurement of Earth Magnetic Field

Since the gyromagnetic ratio of proton is known with precision., the earth magnetic field can be measured by measurement of precession frequency of magnetization M around the earth field as dicussed in section 2.1. In this thesis time interval of known number of cycles of that frequency is measured with precision and the precession frequency can be calculated. The apparatus used is shown by block diagram as in Fig. 5. An e.m.f.of a few microvolts induced in the pick-up coil by the precession of magnetization was amplified by the amplifier. The frequency of the precession is about 1800 Hz. After amplification it becomes audible in a crystal earphone. It was sometimes taped by the tape recorder. The output from the amplifier was further amplified and squared necessary for triggering frequency divider. The frequency divider consists of eleven stages of bistable multivibrator. With proper reset, 2048 input pulses produce one output pulse at the end of 11^{th} stage. The frequency divider requires positive triggering pulse. One positive output pulse was acheived at the 7^{th} stage when 128 pulses had been at the input. The 7^{th} stage positive output pulse was taken and then passed into a start unit. The characteristic of a start unit is to produce one negative pulse when the first positive pulse is at its input, and subsequent pulses can not trigger it. The start unit output pulse was directly fed to electronic

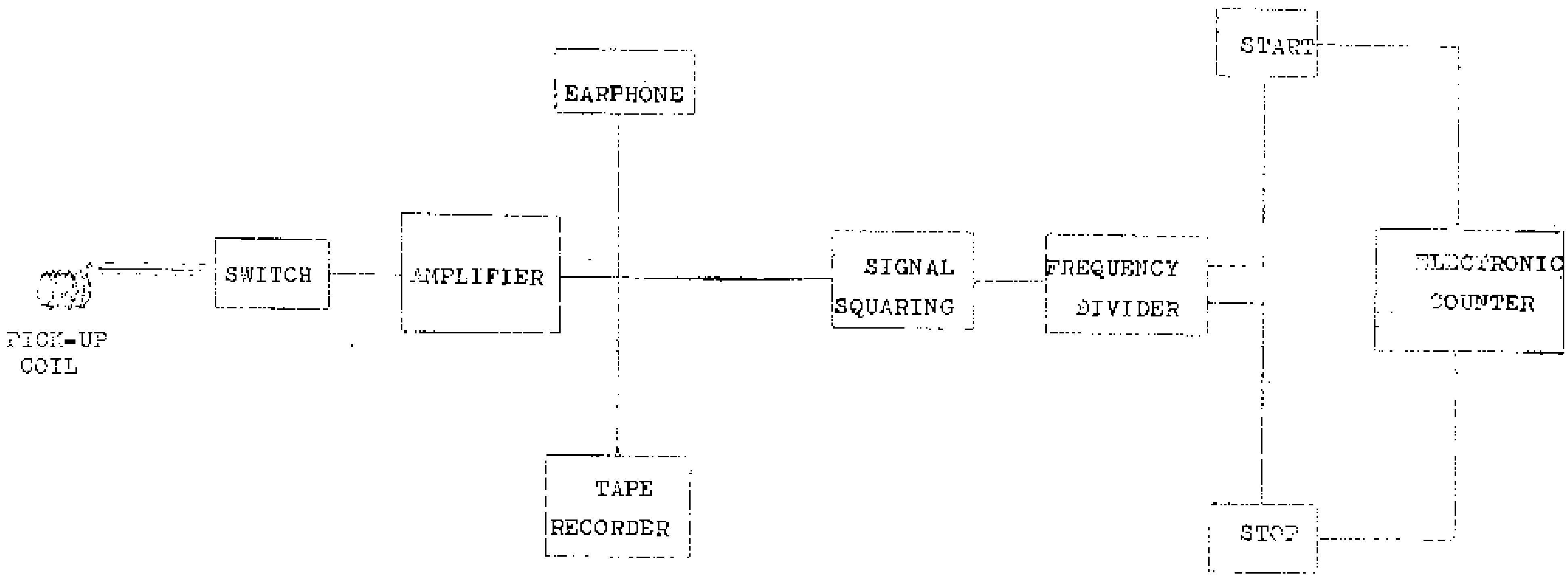


Fig. 5. Block diagram of the apparatus.

counter in order to open its gate circuit. The counter used as a time interval meter started to record the time of every successive pulses that accompanied the 128^{th} pulse until the 2048^{th} pulse was at the input. One positive output pulse would be at the last stage of frequency divider. This pulse was fed to a stop unit whose characteristics is similar to that of start unit. The stop unit output pulse was passed into the input of the electronic counter in order to stop its measurement of time interval. The time interval of 1920 pulses, approximately 1 sec, was measured. The precession frequency was obtained from the time of 1920 pulses. H_1 was calculated by equation f (Hz) = $4257.6H_1$(gauss).

3.2 Functions of Electronic Units

The details of each unit of apparatus used will be described in the following.

3.2.1 Pick-up Coil and Switching Circuit

The pick-up coil is wound on a plastic cylinder of 5 cm. diameter and a length of 6 cm. with 520 turns of No. 24 Standard Wire Gauge enamaled copper wire. The wave winding is divided into four sections of 130 turns each. Coil is tuned at desired frequency of about 1800 Hz by the capacitor of 0.8 microfarad. It is found that Q is approximately 16. The protons or nuclei of hydrogen in distilled water is used as magnetometer in this measurement. The coil is immersed in distilled water in the beaker oriented vertically. The terminals of the coil are connected to switching circuit by a coaxial cable about 6 meters in length. The switching unit and the rest of apparatus is kept far away from the coil in order to minimize the interference effect on the coil. The switching unit consists of two microswitches. The assembly is arranged so that one pressing actuates all two microswitches, as shown in Fig.6.

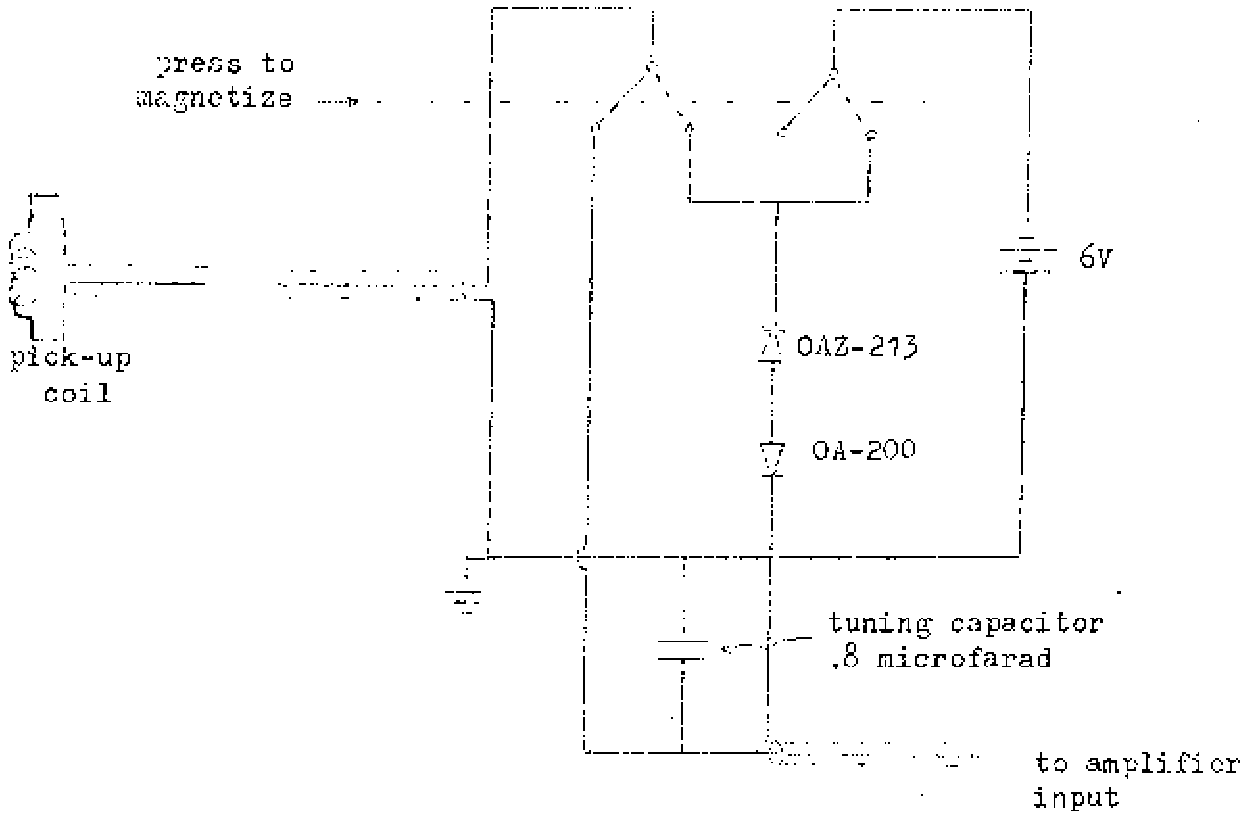


Fig. 6 Switching circuit.

During the pressing, a current of approximately 1 ampere from the 6V heavy duty dry battery serves to magnetize protons in direction of the coil itself which is perpendicular to the earth field. This polarizing field is of the order of 60 oersted. The sample of water with relaxation time of about 3 sec. was magnetized for 5 sec.

When the pressing is released, the battery circuit is broken and then the coil is reconnected to the amplifier. The residual magnetization is now precessing in the earth magnetic field and in so doing induces a signal voltage in the pick-up coil. A Zener diode OAZ-213 connected in series with a conventional diode OA-200 is bridged across the switch contacts of the 6V battery as shown in Fig. 6. These diode minimize sparking at the switch contacts and speed up the collapse of the magnetic field inside the coil when the circuit is opened.

3.2.2 Amplifier

The amplifier whose circuit is shown in Fig. 7 employs five transistors with a tuned transformer through which a narrow band of frequency can be passed. It is an adaptation from a published design(7). First transistor needs to be of low noise, and a small signal transistor 2N2613 is chosen. The following amplifier transistors are OC-71. Noise developed both in the pick-up coil and the first transistor is filtered by insertion of the tuned transformer between the third and the fourth transistors. The anti-parallel diodes at input to the first and the second transistors are used to avoid overloading and for fast recovery after switching. The magnetic core of the transformer is of the pot type. The primary winding of the transformer consists of 120 turns of No. 40 S.W.G. enamaled copper wire. The secondary coil of 1170 turns of No. 40 S.W.G. enamaled copper wire, tapped at 30 turns from the inner end, is wound over the primary. The second winding is tuned at the frequency 1800 Hz by a capacitor .019 microfarad. The peak voltage gain is about 1.2 million, so that oscillation

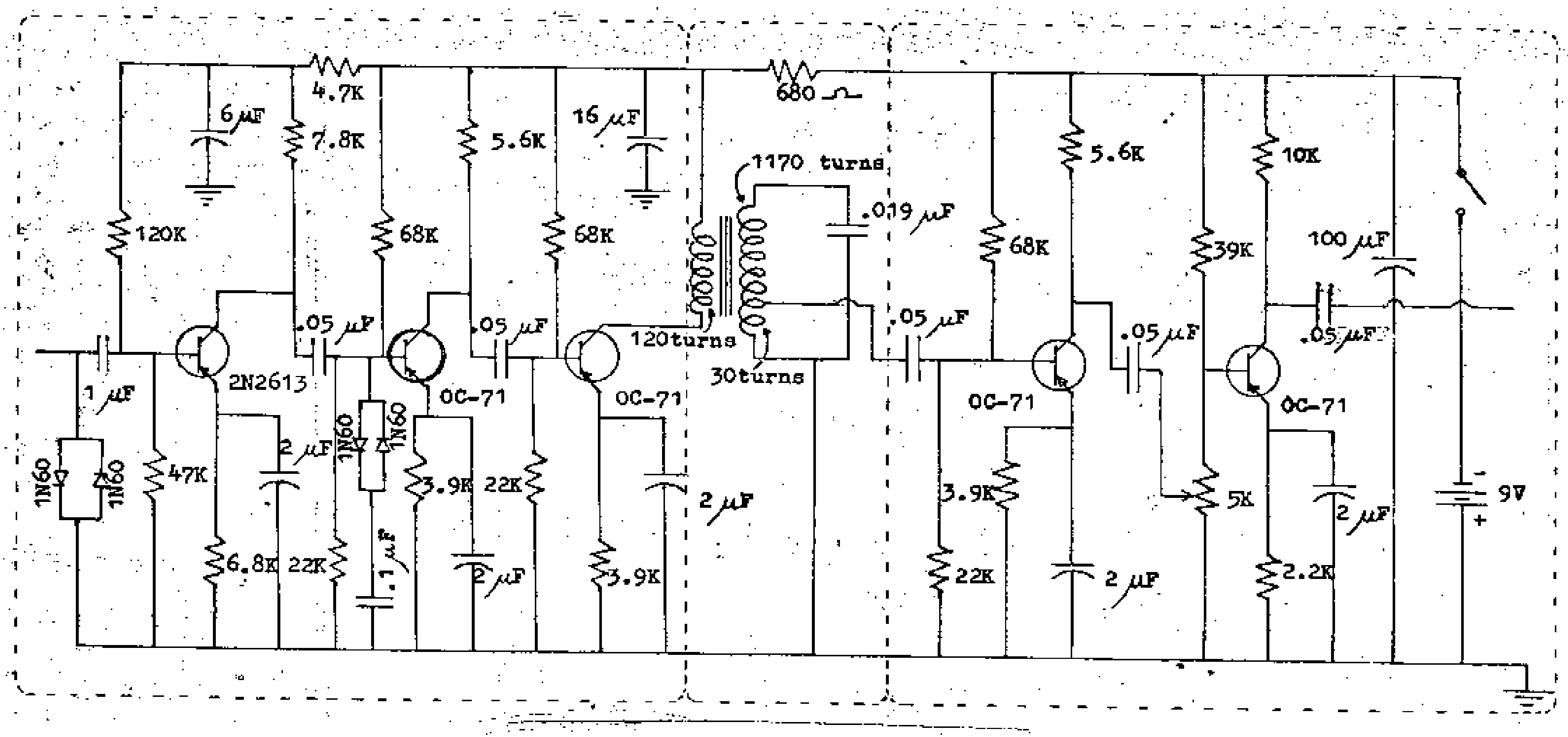


Fig. 7 Circuit of amplifier.

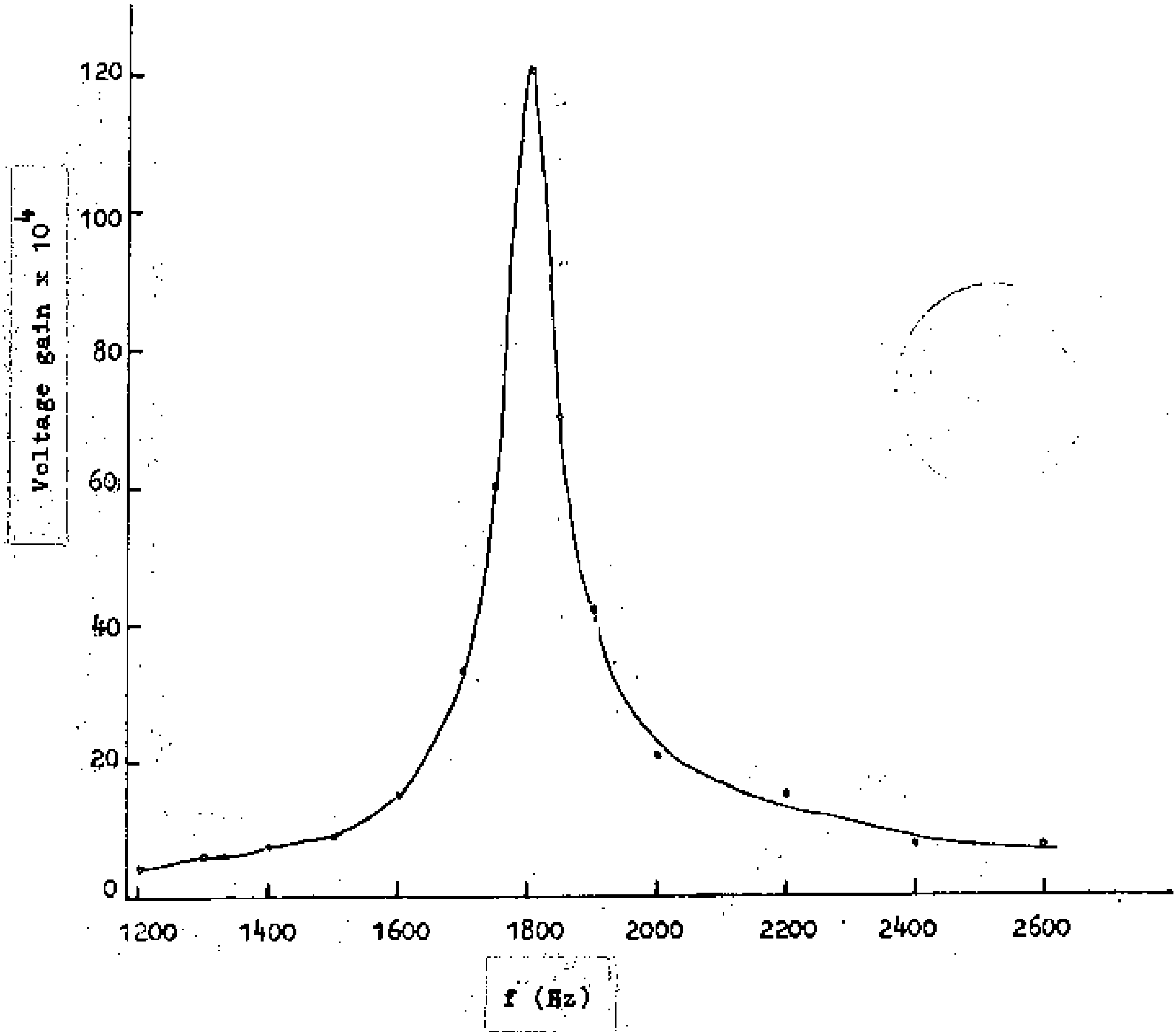


Fig.8. Voltage gain vs. frequency of amplifier

is easily generated. Hence the amplifier and its 9 volts dry battery were installed in a sealed aluminium box. The tuned cicuit was isolated from the remaining parts by aluminium partitions that divided the installation into three compartments and thus shielded the input and output portions of the circuit from each other. The aluminium box was connected to the ground by a copper wire to prevent oscillation. The voltage gain of the amplifier vs the frequency was measured as shown in Fig. 8.

3.2.3 Signal Squaring Circuit

The squaring circuit as shown in Fig. 9 consists of three transistors OC-70. The output signal from the amplifier is further amplified by Q_1 and then passed into Q_2. Q_2 serves as the amplifier operating at saturation. Sufficiently large signal is squared after Q_2. Optimum setting of signal level at input of this signal squaring unit is important to square small signal but not noise. In order to avoid waveform distortion of the square pulse at the frequency divider input, the low output impedance emitter follower Q_3 is employed.

3.2.4 Frequency Divider

A square wave from the output of the signal squaring circuit is divided by frequency divider whose circuit is shown in Fig.10. It consists of eleven stages of bistable multivibrators. Each stage employs two transistors AC 128.

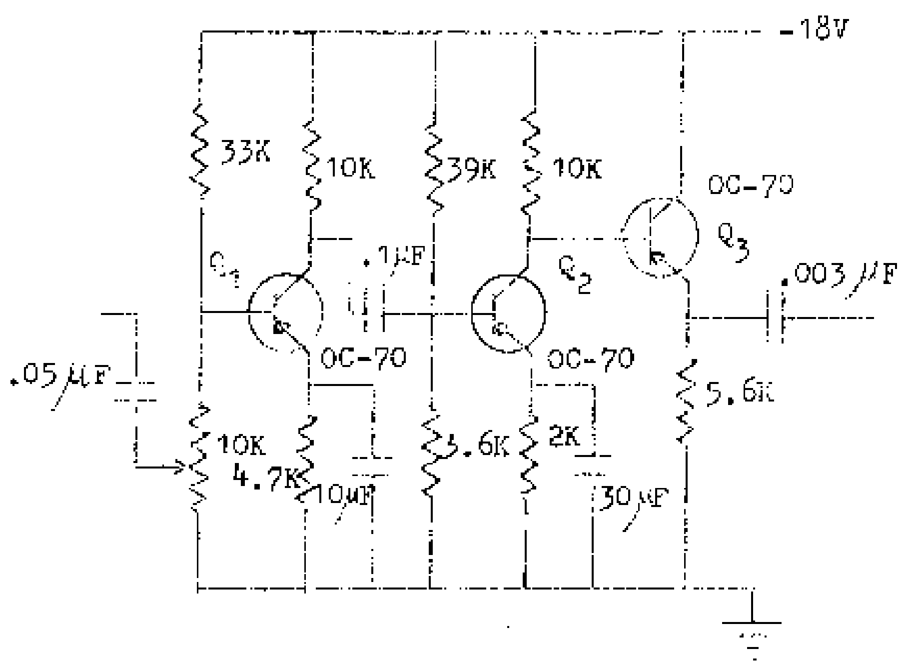


Fig. 9. Signal squaring circuit.

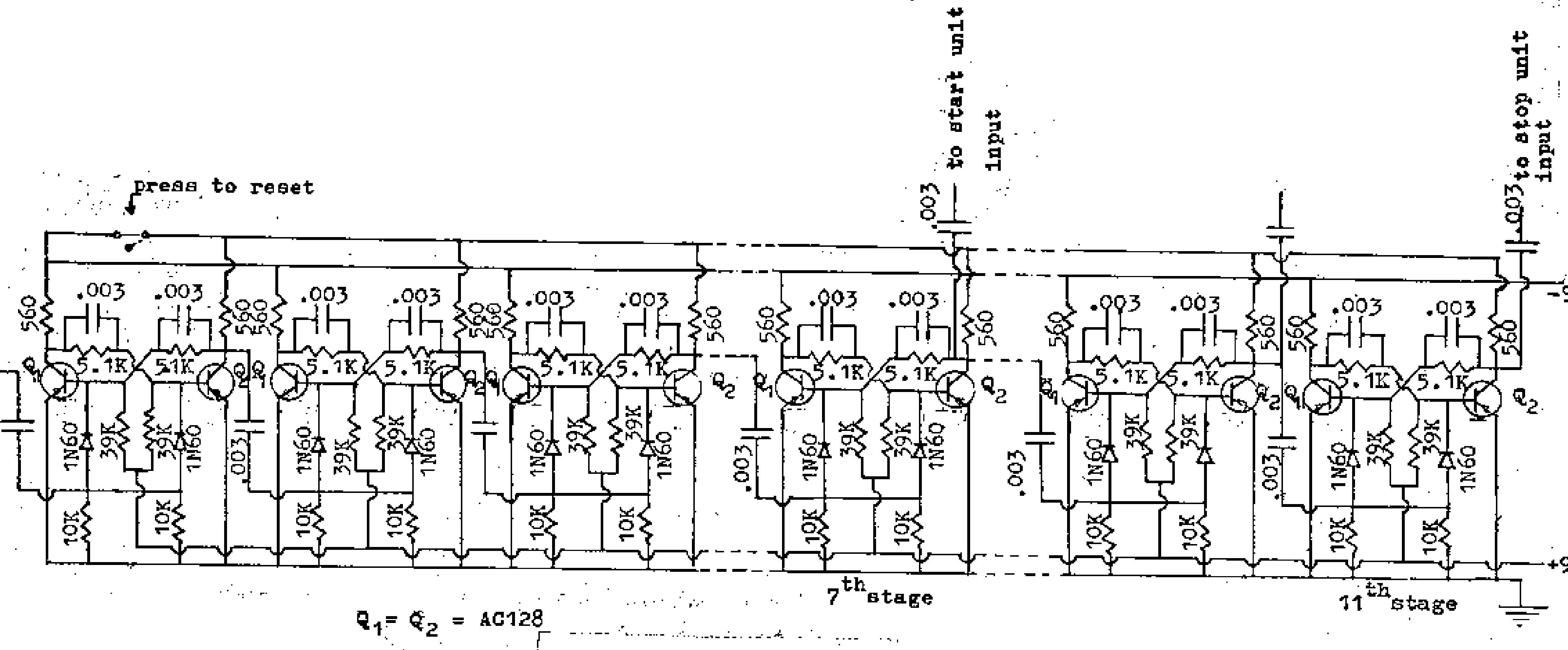


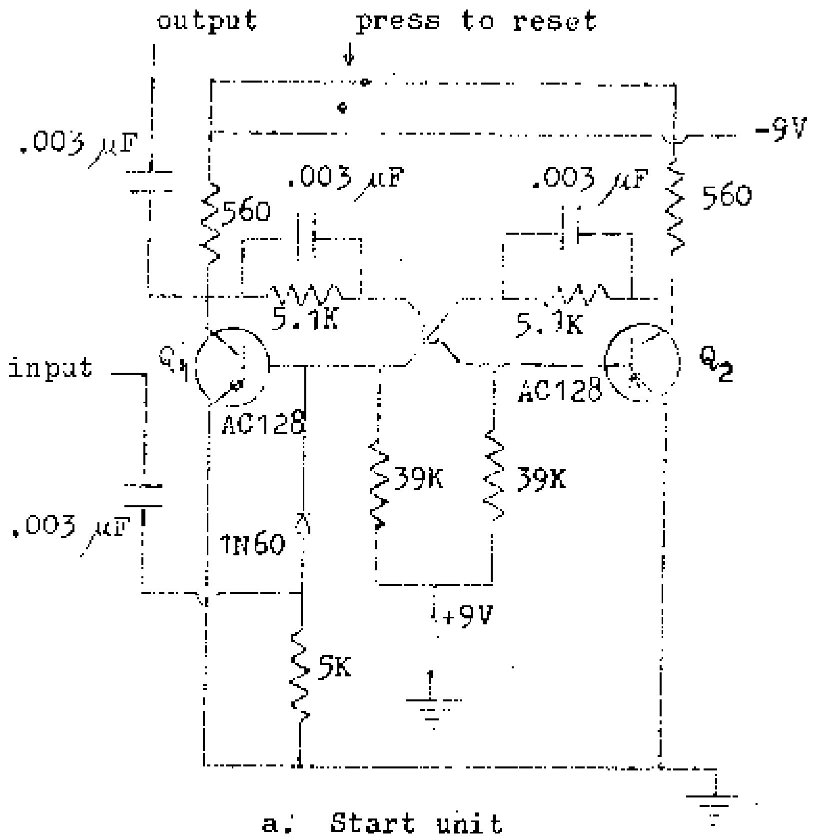
Fig. 10. Frequency divider

With proper reset procedure before time interval measurements Q_1 of each stage is on, Q_2 is off. Positive pulse is required for triggering this circuit. The frequency divider produce one positive output pulse out of every 2048 pulses coming at the input. The positive output pulse from the 7^{th} stage is taken to trigger the start unit and the out put from the 11^{th} stage is fed to trigger the stop unit. Time between the outputs of the 7^{th} stage and the 11^{th} stage is a time interval of 1920 successive pulses coming at frequency divider input.

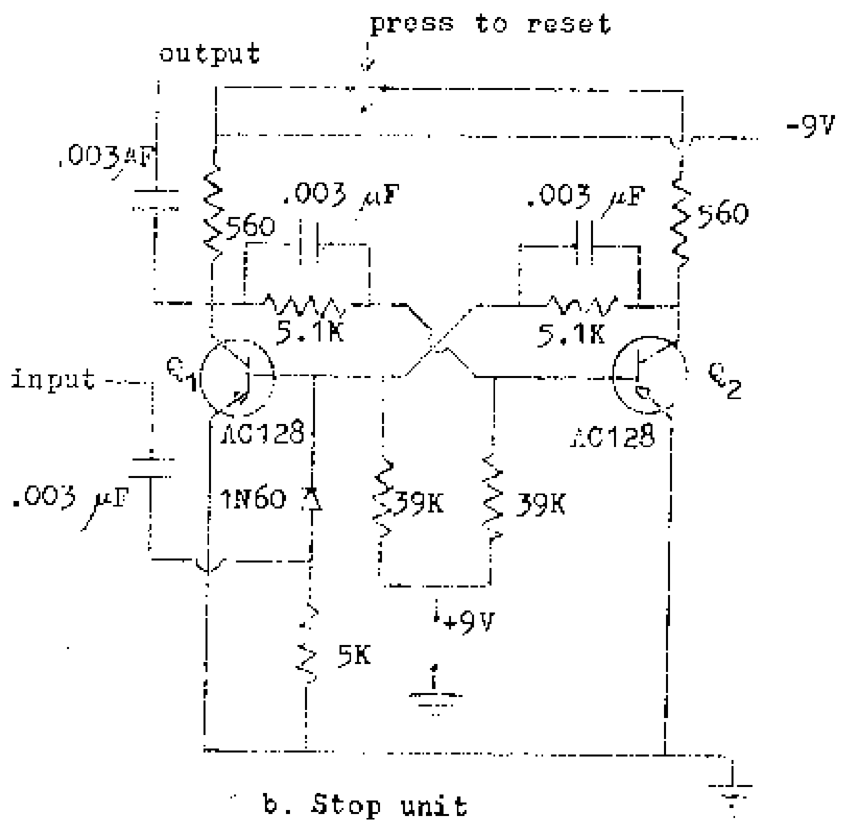
3.2.5 Start - Stop Triggering of Time Interval Measurement

Time interval of 1920 cycles of signal frequency was measured by Hewlett Packard Model 5216A Electronic Counter. Two negative pulses are required for triggering "start" and "stop" of the time interval measurement by the counter. The negative pulses are provided by start and stop units whose circuits are shown in Fig.11. It is one stage of bistable multivibrator but the diode at the base of Q_2 is omitted. Thus the bistable multivibrator accepts triggering on one side only. Working of the start and stop units is the same, that is, to produce one negative pulse for the first positive pulse coming to it (provided reset is properly set).

The time interval accuracy depends on the internal time base of the Hewlett Packard Electronic Counter which has a 10 MHz crystal oscillator as reference. The manufacturer's specifications give stability of time base as less than $\pm$ 2×10^{-6}/month for aging rate, less than $\pm$ 1×10^{-5} for +15°C to 35°C temperature change and less than 1×10^{-6} for $\pm$ 10 % change in line voltage.



a. Start unit



b. Stop unit

Fig. 11. Circuits of start and stop units.

3.3 Problems of Measurement

In this experiment the electronic counter was used to measure the time interval from the 128^{th} pulse to the 2048^{th} pulse. The starting before the 128^{th} pulse has been attempted, but time interval readings have larger fluctuation. This might be due to left-over polarizing field in the coil after switching off. This field gives rise to an oscillating current in the coil. A second problem is the inhomogeneity of the magnetic field at the pick-up coil. In order to avoid this problem, experiment must be performed sufficiently far away from buildings and pieces of magnetic materials. The field in front of the Auditorium of the Chulalongkorn University was chosen for this measurement. It was found that time interval measurement could not be carried out before 4 p.m. because of excessive noises. On some days the experiment has to be delayed till as late as 6 p.m.