Portable Secondary Frequency Standard

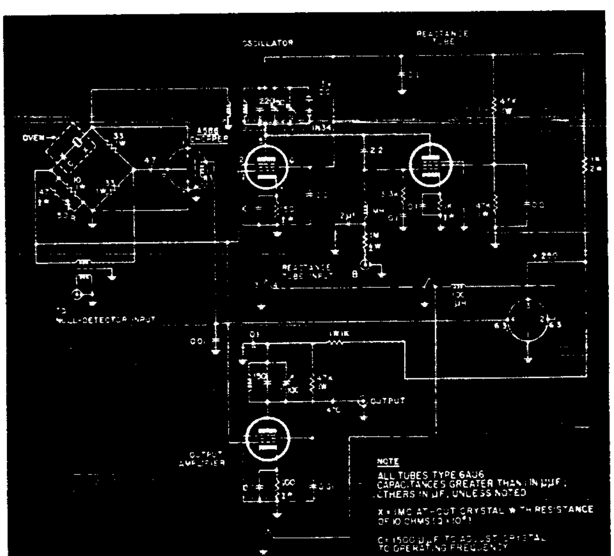
THE BUREAU has designed and constructed a compact, high-stability one-megacycle frequency standard, constant to a few parts in 1 billion per day. The standard employs an oscillator and a one-megacycle AT-cut quartz crystal unit in a bridge-balancing frequency-correction system. Developed by Peter G. Sulzer of NBS, the standard produces a frequency which is almost entirely independent of tube, component, and supply-voltage changes. Because of its convenient size and its use of relatively inexpensive, commercially available components, this secondary standard should prove to be a valuable tool both in the laboratory and in the electronics and communications industries.

A widespread need exists for highly accurate secondary standards of frequency and time. Such standards aie used for checking radio transmitters, making astronomical measurements, calibrating precision clocks, and a variety of other scientific measurements. In an effort to provide such standards, NBS is conducting a research program aimed at improving the characteristics of crystal-controlled oscillators.

Experiments have shown that the characteristics of a crystal unit can be measured precisely in a resonance bridge. If an oscillator is adjusted to resonance with a highly stable crystal unit, the resonant frequency of the unit can be measured with a resolution of 1×10^{-10} or better. Such a system constitutes a useful frequency standard, particularly if continuous frequency adjustment is made by automatic means.

An experimental model of a bridge-balancing oscillator developed by NBS as a convenient, inexpensive secondary standard of frequency. This equipment provides a frequency accurate to a few parts in 10 billion per day and should prove useful in a variety of technical fields.

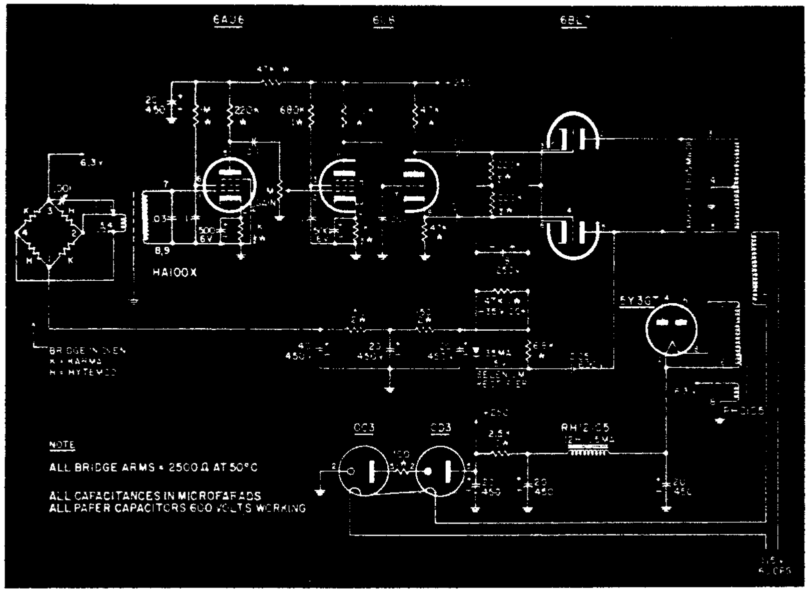
Schematic diagram of oscillator, reactance tube, and output amplifier used in the NBS secondary frequency standard. Some simplification of the circuitry was realized by making the crystal unit common to the bridge and the controlled oscillator.



In the system developed at NBS, the crystal unit is connected in a low-impedance bridge. The bridge is driven by an oscillator whose frequency is variable over a small range. If the frequency of the oscillator differs from that of the crystal, the bridge produces an output voltage which is amplified by a null detector and rectified by a phase detector. The output of the phase detector is then used to actuate a control which decreases the frequency error. This form of control has been used by others.[1]

Two arms of the bridge consist essentially of a crystal unit (which may be called X) connected in series with a resistance (R) which is equal to the series-resonant resistance of X. These two circuit elements, together with an amplifier, also constitute a simple oscillator which oscillates near the series-resonant frequency of X. The bridge is completed by the addition of two equal resistances of a somewhat higher value than R. Since the crystal unit is common to the bridge and the controlled oscillator, some simplification of the circuitry is realized.

In operation a small capacitor (C) is switched alternately across one or the other of the equal bridge arms by means of a chopper. The bridge output is fed into the null amplifier, which has a voltage gain of approximately 10^7, and is rectified by another tube. Two other capacitors are charged alternately in synchronism with the switching of C by means of a second chopper. The difference in the voltages across these two capacitors is used to actuate a reactance tube which varies the frequency of the oscillator over a small range.



Schematic of the temperature controller used in NBS high-stability oscillator. Circuitry is designed so that a change of 22° C in ambient temperature will produce a change of only 10^{-3}° inside the oven. Such temperature control is necessary to obtain high-frequency stability.

If there is no frequency difference between the oscillator and the crystal unit, equal bridge outputs are obtained for the two switched positions of C. When this happens, equal voltages are placed across the two capacitors, and the reactance tube is not actuated. If a frequency error does occur, however, different bridge outputs are obtained for the two positions of C, and frequency correction takes place.

To realize the utmost in frequency stability, the crystal unit must be operated at a constant balance-temperature. In the NBS oscillator a temperature-sensitive bridge, which is wound on the walls of the crystal-unit container, is supplied with a small amount of line-frequency power. If the bridge temperature differs from its balance temperature, an alternating output voltage at the line frequency is obtained. The output is amplified and applied to a phase-sensitive detector, which produces a direct voltage proportional to the bridge-unbalanced voltage. The d-c voltage is applied to the bridge, and the resulting heating power tends to drive the bridge to a balance.

[1] Quartz resonator servo—a new frequency standard, *by Norman Lea, The Marconi Review,* **17**, *No. 114, 65 (1954)*.

Schematic diagram of the null amplifier and detector used in secondary frequency standard.