FREQUENCY STANDARD
Continuous Coverage Interpolating Standard for Accurate Frequency Determinations

Fig. 1. Front View of the Frequency Standard. Main Tuning Dial on the Left,Bloking Oscillator Frequency Control in Middle, Output Control on the Right.

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CIRCUIT CONSTANTS

- \( L_a = 10 \) millihenry air core inductance with center tap (Millen #34120-1)
- \( R_a = 0.1 \) meg. \( \Omega \) watt
- \( R_b = 150 \) ohm. \( \Omega \) watt
- \( R_c = 6.750 \) meg. \( \Omega \) watt
- \( R_d = 10,000 \) ohm linear potentiometer
- \( R_e = 75,000 \) ohm \( \Omega \) watt
- \( R_f = 100 \) ohm potentiometer
- \( R_g = 100 \) ohm
- \( L_a = 8 \) millihenry air core inductance (Millen #34008)

Frequency measuring work is done by every amateur each time he has a QSO. He may use his receiver, or a 100 kcrystal, or a calibrated VFO, or some other frequency measuring device. Whatever the method, he knows that the amateur he is working in is a certain band of frequencies, and similarly, he knows that he himself is transmitting in a certain band of frequencies. This is frequency measurement of a sort, although the percentage of accuracy is not very good.

In an endeavor to increase the percentage of accuracy, many amateurs use 100 kcrystals, so that hard edges can be spotted accurately. If this is done in conjunction with a receiver using adequate bandwidth, and with a nearly linear dial, it is possible to make frequency readings to within ten kilohertz or so.

In order to get accuracy beyond this point, it is usually necessary to go to so-called secondary frequency standards. The "secondary" refers to the fact that the standard is adjusted to some primary standard, such as WWV, so that the standard now becomes a second, or secondary standard. There are two types of secondary standards. One is the fixed frequency standard. This consists of a fixed frequency oscillator, usually using a crystal, and a means of generating sub-multiples of the fixed frequency. For example, a 100 kc crystal oscillator with, or without a 10 kc multi-vibrator is such a standard.

The other type is the interpolating standard which is the type about to be described. This type differs from the fixed-frequency type in that the second frequency of the oscillator goes to a frequency. The standard shown in Fig. 1 has a fundamental frequency range which is variable from approximately 100 to 10,000 kilocycles. In addition, a frequency divider produces ten kilocycle frequency steps.

Therefore, if this standard were set at 100 kilocycles, the tenth harmonic could be heard on a receiver at 1000 kilocycles. At 10 kc the first ten kc step could be heard. Now assume that a signal existed at 1000 kilocycles. By tuning, on the standard, until the standard's signal was zero beat with the 100 kc signal, you would find that the dial had been moved just ninety degrees, so that the standard was now generating a signal at 1005.5 kilocycles. Meanwhile, the ten kilocycle marker beat at 10 kc would now be heard at 1015 kc. The exact use of this standard will be described later, but it can be seen that any unknown signal can be zeroed on the standard, and the frequency accurately determined.

ELECTRICAL DETAILS

Referring to the circuit diagram, Fig. 2, the 6AK5 on the left is the variable frequency oscillator. L is the grid coil, C1 the main tuning condenser, C2 the fixed plate condenser, and C3 the adjusting plate condenser, which enables the frequency to be set to exactly 100 kc when C3 is set at zero on the dial. The circuit is a Clapp type of oscillator, which has become so popular recently because of its high order of stability.

The oscillator feeds into another 6AK5 tube which acts as a blocking oscillator. A blocking oscillator is used as such because the blocking oscillator takes much less current (about 0.1 mill) and therefore contributes practically no heat to the unit. Potentiometer R4 allows the frequency of oscillations to be varied, so that the stage may be set for ten kilocycles. The output from the frequency standard may be controlled by R5.

The circuit shown requires very little power to operate it. The high-voltage rectifiers are 100 volts at approximately 10 ma, while the filament requirements are 6.3 volts at 0.330 amperes. This means that practically no heat is generated, so that temperature compensation is not necessary. Because of the small power requirements, it is possible to supply plate and filament power from a
receiver. In this case, the voltage used should be 100 volts, as specified, as the unit has been designed to operate at this approximate voltage only. A voltage regulator tube, such as the G.L.-031/VR-105, would make an excellent source of power, although a voltage regulated supply is not required.

Two suggested power supplies are shown in Fig. 3. The supply shown in Fig. 3A is a voltage doubler, which insures that 100 volts output will be obtained. Two filament transformers are used, back-to-back, to give a-c line isolation. The supply shown in Fig. 3B is a half-wave rectifier which operates directly from the a-c line. If this supply is used, care must be taken to see that proper a-c polarity is obtained when connecting the power supply to the line.

**MECHANICAL DETAILS**

Fig. 1 shows the complete frequency standard in a 1 by 5 by 9 inch cabinet. The dial on the left is the main tuning control, the middle knob is R1, and the knob on the right is R2. The output is taken from the two terminals at the upper right.

An exposed view of the front panel, cabinet and power supply is shown in Fig. 5. The frequency standard proper is mounted on the front panel by means of a 3 by 4 by 5 inch box. The power supply is mounted on a 3/4 by 5/8 inch piece of 1/4 inch thick aluminum or steel, and fastened to the back panel of the cabinet by 5/16 inch metal hinges.

A rear view of the frequency standard proper is given in Fig. 4. In the right-hand portion of the 3 by 4 by 5 inch box will be the main tuning condenser (C), with the tuning condenser (C2) mounted below. The outer condenser is mounted on the side of the small box. It is adjusted through a hole cut in the cabinet (see Fig. 3). Directly above C is L3, and to the right of L3 will be seen C6 and C7. These condensers are fastened to the box by a small metal strap. The slider from an adjustable resistor works very nicely for this panel.

The left-hand panel of the small box contains the two tube sockets and the remainder of the components, except for the switch which is secured directly to the front panel outside the box. The schematic of Fig. 6 shows how the various components are placed. Two components were deliberately left out of the sketch, for the sake of clarity. C6 should be connected to the B plus terminal of the four terminal strip and to pin 1 of the 6AK5 blocking oscillator tube. Condenser C1 is connected from pin 3 of the 6FQ7 tube to pin 1 of the BO tube, if it is necessary. This will be explained later.

**CONSTRUCTIONAL DETAILS**

Two of the parts specified may be critical, and on these parts no substitutions are recommended, unless the builder desires to do extra experimentation. These parts are recommended because they are readily available and give a high Q in order for the 6AK5 oscillator to operate properly. The Miller 64030 coil has been found very satisfactory. Coil L4 is even more critical, as the proper operation of the blocking oscillator depends upon the proper coupling between the two halves of coil L4. The Miller 64010-1 coil will operate satisfactorily. It is also strongly recommended that a National Type N dial (scale 2) be used for the main tuning dial. It is possible to read this dial accurately to one part in a thousand, for 180 degrees rotation. One division (out of a hundred) equals approximately ten cycles change in the variable frequency oscillator's frequency. The vernier permits reading to one-tenth of a division, which is a frequency change of one cycle. The stability of the Clapp oscillator more than justifies use of a dial which can be read to this accuracy.

The first step in the construction of the frequency standard is to mount the small box on the front panel of the cabinet. This is a job which requires checking with the tuning condenser used and the tuning dial so that the tuning dial is centered on the front panel and so that the tuning condenser mounts against the side of the small box. In general, the Type N dial will have its short center in from the left side of the cabinet approximately 1/4 inch. The vertical dimension will be the exact center point of the dial on the front panel. The dial template will help in this step.

When the hole for the dial is drilled, then the small box is mounted so that the tuning condenser can be held against the side of the box and main
with the tuning dial. It may be necessary to cut off part of the shaft on C. Fig. 4 gives the details of the bracket used to mount C. Two are used. The small box is centered vertically on the front panel, and is placed approximately 1 3/8 inches from the edge of the cabinet in a horizontal direction.

Controls R3 and R4 are mounted 1 1/8 inches up from the bottom of the panel and 1 1/8 and 2 1/2 inches respectively from the right hand edge of the panel.

The small box can now be removed from the front panel and the remainder of the parts mounted. Coil L6 should be mounted only by the two holes in the isolating base. Spacers made of washers will hold the coil far enough off the chassis so that the connecting lugs do not touch the chassis. Do not put any machine screw through the center hole. Mount as shown in Fig. 4. The components in the box are then completely connected, except the connections to R5 and R6. The small box is then mounted on the front panel and connections made to R5 and R6. Recommended that the layout of parts as shown in Fig. 6 be followed closely. This layout is efficient in its use of space, and gives sufficient isolation between the two stages. This is important.

**TUNE-UP ADJUSTMENTS**

Measure the d-c voltage applied to the unit and adjust until it is approximately 100 volts. If the power supply circuit in Fig. 3A is used, the voltage may be adjusted by increasing or decreasing R4. The same thing is true of R5 in Fig. 3B.

Remove the 6AK5 blocking oscillator tube from its socket. Set the main dial to zero. Check the frequency of the variable oscillator by beating the 50th harmonic against W5V at 5000 kc. Adjust to zero beat by means of C5. The unit should have warmed up for about 15 minutes before this is done. At this point it is desirable to check the operating level of the variable frequency oscillator. The d-c bias on pin 1 of the VFO tube should be between 3 and 4 volts as measured with a VTVM, or by means of a 20,000 ohm high resistance meter. In the latter case use the 10 volt scale and use a new pogo wire resistor at the end of the negative test lead where you connect to pin 1.
If a sufficiently strong signal is not heard in the receiver, take the back off the 3 by 4 inch box and search for the oscillator by bringing a lead close to the plate circuit.

The next step is to determine the exact frequency change incurred when the main tuning dial is tuned through 180 degrees. This may be done several ways. The easiest method is to tune in WWV at 10,000 kc. The 100th harmonic of the oscillator should be heard at zero beat with WWV. Now tune the dial until zero beat is again heard. This will be with the dial tuned through approximately 150 degrees, if the circuit constants have been followed carefully. As the dial is tuned the frequency increases. When the frequency is exactly 101.01 kc the 99th harmonic is at zero beat with WWV at 10,000 kc. By noting the dial reading and taking the ratio between it and full scale, the exact frequency range of the dial can be determined.

For the purpose of further explanation, let us assume that the dial was found to cover 100 to 101.250 kilocycles when going from zero through 100 divisions. This means that each division of the 100 divisions on the dial represents a change of 1.250 cycles. The dial readings will be linear because of the relatively small frequency range covered.

Now put the SK20 in the oscillating circuit and then adjust the SK20 trimmer, using each of the four pins with fine steel wool. This may be an unnecessary precaution, but a form of purification is always advised. When this is not done, condenser C1 should not be wired in at this time.

Set C1 to zero and tune in the signal on a relatively low frequency. Tune the receiver BFO on. Tune the receiver slowly. There should be a beat each ten kilocycles when R1 is properly adjusted. Listen on the even 100 kc points as you adjust R1. The frequency will be found to lock up at each place. If this is not true, add C1 to the circuit. Try 5 mmf. Experiment until beats are heard regularly and clearly. Once C1 is in the proper value (more than 10 mmf should not be necessary, and it is possible that C1 may be omitted entirely) double check to determine if the blocking oscillator is producing 10 kc steps. If not, it may be necessary to change the value of either R1 or R2. Both 9 kc and 11 kc steps may be heard by adjusting R2. Once 10 kc steps are heard in the receiver, the unit is ready for use.

**of THE FREQUENCY STANDARD**

The proper use of this frequency standard can be obtained by means of an example. The frequency must always be kept in mind, and that is the number of cycles per second of the fundamental frequency that is represented by one division of the main tuning dial. We shall assume, for this discussion, that this factor is 12.50 cycles per division.

Next assume that you wish to measure the frequency of a signal which is somewhere between 3900 and 4000 kilocycles. This assumes that you have previously calibrated your receiver with the frequency standard so that you know the dial readings for 3900 and 4000 kilocycles. Now, with the frequency standard set at zero, the 39.9th harmonic of the fundamental frequency is below the unknown. By tuning the main dial on the frequency standard this 39.9th harmonic is heard at a frequency such that it gives zero beat with the unknown.

Assume the dial reading, when zero beat is obtained, is 7.0 divisions (not of 100). We have therefore moved the fundamental frequency 7.0 times 12.50 or 87.5 cycles. Therefore, the unknown frequency is 87.5 times 39.9 or 3491.25 cycles above 3900 kc. The actual frequency of the unknown is therefore 3990.00 plus 3491.25 or 3931.25 kilocycles.

As a double check, we can keep tuning the main dial on the frequency standard until the 39.8 harmonic moves up to zero beat with the unknown.

The second reading may be, for example, 27.1 divisions. This change is of 12.50 times 27.1 or 338.75 cycles. This time 29.8 is 12.50 times 23.5 cycles. This added to 3900.00 is 3933.45 kilocycles. This read is 9 cycles off from the first. The two readings may be averaged for a final reading.

It will be seen from the above that the reading accuracy is about 40 cycles at 4 megacycles, or 10 parts per million. This is the so-called, 'short term' accuracy, based on checks against WWV every hour or so. The long term accuracy will depend on how well the unit is constructed, the ambient temperature conditions, and the effective temperature coefficient of the components used.
GLASS TO METAL SEALS
Question: How is the glass to metal seal accomplished in miniature tubes?—J. L. Stafford.
Answer: The glass envelope of a miniature tube (either the 7- or 9-pin type) is formed from two pieces, a glass bulb and a glass stem. These pieces are joined near the point where the metal leads come through the stem. This sealing operation is the last bit of assembly work done prior to exhaust.
The glass stem is a flat button of glass with the metal pins, or leads, going through the glass and being sealed to it. The leads are usually several pieces of metal welded end to end. For example, a lead may consist of a piece of nickel (which serves as the pin) welded to a piece of dunn, which is welded to a second piece of nickel. The second piece of nickel is inside the bulb and connects to the tube elements.
The glass in the bottom base is sealed to the dunn portion of the lead by the application of heat to both the glass and the lead. An air tight seal is made possible, despite differential expansion of the lead and the glass, due to the way dunn is made. Basically, dunn is a piece of copper-clad iron. The glass adheres to the thin copper sheath. As changes in temperature cause the glass to expand and contract, the thin copper sheath is able to follow this movement without causing an air leak.
Manufacturing a miniature tube therefore follows this pattern. The glass stem is made by sealing seven (or nine) leads into a glass button. The tube elements are mounted on the leads. The glass bulb is slipped over the elements and sealed to the glass stem.—Lighthouse Larry.

6-B TUBE OPERATION
Question: With tubes such as the 6BP1, 6AP1, etc., the cathode is connected to one side of the filament internally, making it necessary to use a filament transformer which is insulated to stand the voltage on the cathode, which may be a thousand volts or more. However, tubes such as the 5CP1, 5RP1, etc., have a separate cathode lead brought out on a separate lead. Is it necessary to have the transformer grounded, so that an insensitive transformer may be used? Also, will the phosphor of cadmium-ray tubes lose its fluorescent properties, or otherwise deteriorate, if the tubes are stored for a period of four or five years without use?—W. W.
Answer: In the case of cadmium-ray tubes where the cathode is not connected to the filament internally, it is recommended that the cathode be connected to the negative side of the filament winding. This means that a well-insulated transformer is required. In the event that this connection is not made, these tubes are rated to have no more than 140 volts between the cathode connection and either of the two filament leads.

There should be no deterioration taking place in a cadmium-ray tube stored as you state.—Lighthouse Larry.

DISCLOSING OF RULES
Question: What causes the silver color on the glass bulb of high vacuum rectifiers such as the 352-GT and the 352-E-GT after they have been used for several months?—R. Wagner.
Answer: This effect will be noted in many types of tubes. The silver color is caused by a very thin deposit of metal. The metal may be magnesium, martenstic, nickel, etc., or a combination of metals, depending on the type of tube involved.
Almost any type of metal, when evaporated and deposited in a thin layer on the inside of a vacuum tube, will appear as a silvery or mirror-like finish. The same effect causes the silver color of the getter material which is deposited on the inside of the bulb at the time of manufacture.—Lighthouse Larry.

METAL V. GLASS TUBES
Question: Are there any general rules that can be made as to the selection of metal tubes over glass tubes, or vice versa, as to radiation of heat, shielding, microphonics, maximum usable frequency, etc.?—H. Van Valkenburg.
Answer: It is assumed in this question that the term glass tubes refers to the large-size tubes, and not to miniature tubes. In this case, no general rules can be given, but a discussion of relative merits might be in order.
A metal tube will certainly radiate more heat from its metal shell than a glass tube will from its glass envelope. However, the glass bulb permits the loss of radiant heat energy through the glass bulb, so that a metal tube shell must, of necessity, be capable of withstanding much heat. There cannot be too much difference in the total heat-releasing capabilities of glass vs. metal, as similar types of tubes are given the same rating.
Metal tubes are superior from the shielding standpoint. Even though a glass tube uses an external metal shield, this shield is liable to cause circuit noise. There is no equivalent to the metal shield that can be made concerning the maximum usable frequency, as this ties in with the tube type under con-
TRICKS AND TOPICS

How did you solve that last problem that almost had you stumped? Be it about tubes, antennas, circuits, etc., Lighthouse Larry would like to tell the rest of the hams about it. Send it in! For each "TRICK" published you win $10 worth of Q-9 Electronic Tubes. No entries returned. Mark your letter "Entry for Tricks and Topics" and send it to Lighthouse Larry, Tube Division, Bldg. 269, General Electric Company, Schenectady, New York, or in Canada, to Canadian General Electric Company, Ltd., Toronto, Ontario.

ROTARY JOINT FOR BEAMS

Recently, when I got the urge to put up a ten meter beam, I was faced with the usual problem of providing 360 degree rotation without winding the feed line into a twisted mess. Fig. 9 shows how this problem was overcome. Because these types of coaxial connectors are readily available at low prices at the present time, the over-all arrangement is inexpensive and yet very satisfactory in performance.

The 82-1R connector is bolted to the pipe flange and the latter is fastened securely to the pipe after connecting the coaxial cable to the 82-1R connector. The flange and the 82-1R connector are then free to turn as the beam turns, while the elbow and the 82-1RP connector are stationary.

After assembly the collar of the 83-1AP elbow may be soldered to the 83-1R connector to prevent the collar from loosening, and to make a better electrical connection.

There may be an impulse discontinuity present at the rotary joint, but it should be less than in other types of rotary joints. At any rate, it has been in use for over a year, has given no trouble, and I have worked over fifty countries with the beam.—W7ISO.

(Rd’s note: This arrangement is probably not completely waterproof. A covering of some sort is therefore advisable.)

INDEX MARKING FOR CALL BOOK

A very easy way to make a set of thumb index marks for your call book without cutting or pasting on cumbersome tape is described below. This may not be original but the writer discovered this simple and effective method. All that is needed is a bottle of black ink (preferably India ink) and a pen.

Open the call book to the first district. On the right edge of the right page make a mark 1/4 in. wide and 3/4 in. long, starting about 3/4 in. from the top of the page (Fig. 10). Then open the call book to the second district and make a similar mark, starting about 1/4 in. below the bottom of the mark of the first call area (as shown at “b”). Follow this sequence through the book for each call area and each major foreign country, including any of your favorite DX areas, ending with the Q signals.

After this is done, fold the book so that the cut edges fan out about 3/4 in. wide. The black marks can then be easily seen. In front of each of the marks print the corresponding number of the call area or the foreign prefix.—W2PEN.
**GENERAL INFORMATION**

**6AK5**

Principal Application: The 6AK5 is a miniature radio-frequency amplifier pentode with sharp cut-off characteristic. Its high transconductance combined with low interelectrode capacitances and the short lead lengths obtained as a result of its miniature construction enable this tube to be used effectively as a radio-frequency amplifier at frequencies up to approximately 400 megacycles.

**Mounting Position**: Any

**Direct Inter-electrode Capacitance**

<table>
<thead>
<tr>
<th>Grid to Plate (Max)</th>
<th>0.03 µf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid to Grid (Max)</td>
<td>4.0 µf</td>
</tr>
<tr>
<td>Plate to Grid (Max)</td>
<td>1.5 µf</td>
</tr>
</tbody>
</table>

**MAXIMUM RATINGS**

<table>
<thead>
<tr>
<th>DC Input Voltage</th>
<th>180 Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Output Voltage</td>
<td>180 Volts</td>
</tr>
<tr>
<td>Grid to Cathode Potential</td>
<td>250 Volts</td>
</tr>
<tr>
<td>Plate to Cathode Potential</td>
<td>210 Volts</td>
</tr>
<tr>
<td>Plate Dissipation</td>
<td>2 Watts</td>
</tr>
<tr>
<td>Grid Dissipation</td>
<td>2 Watts</td>
</tr>
<tr>
<td>Numer Potential</td>
<td>150 Millivolts</td>
</tr>
</tbody>
</table>

**CHARACTERISTICS AND TYPICAL OPERATION**

<table>
<thead>
<tr>
<th>Plate Voltage</th>
<th>150 Volts</th>
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</thead>
<tbody>
<tr>
<td>Screen Voltage</td>
<td>145 Volts</td>
</tr>
<tr>
<td>Cathode Bias Resistor**</td>
<td>300 Ohms</td>
</tr>
<tr>
<td>Plate Resistance (Approximate)</td>
<td>6.4Ω</td>
</tr>
<tr>
<td>Plate Current (Approximate)</td>
<td>500 mA</td>
</tr>
<tr>
<td>Plate Dissipation</td>
<td>1 W</td>
</tr>
<tr>
<td>Screen Current</td>
<td>1.0 Milliamperes</td>
</tr>
<tr>
<td>Grid Current</td>
<td>1.1 Milliamperes</td>
</tr>
</tbody>
</table>

* With RMA standard shield No. 336 connected to cathode.

** Fixed-bias operation is not recommended.**

**SAXINO DIAGRAM**

**TERMINAL CONNECTIONS**

| Pin 1—Grid | Pin 2—Plate |
| Pin 3—Cathode | Pin 4—Grid |
| Pin 5—Grid | Pin 6—Grid |
| Pin 7—Grid, Internal Shield | Pin 8—Plate |

**GENERAL ELECTRIC**

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