SYNCHRONIZER FOR OSCILLATORS

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Richard L. Campbell INVENTOR.

BY

Charles W. Martines
ATTORNEY
R. L. CAMPBELL
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Fig. 2

Richard L. Campbell
INVENTOR.

BY

Charles W. Montiner
ATTORNEY
SYNCHRONIZER FOR OSCILLATORS

Richard L. Campbell, Maywood, N. J., assignor to
Allen B. Du Mont Laboratories, Inc., Passaic,
N. J., a corporation of Delaware

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This invention relates to a synchronizer for oscilla-
tors by means of which the frequency of the oscilla-
tor can be controlled by the signal with which the oscillator is to be synchronized.

With this invention a control tube for an oscil-
lator is operated normally at zero potential, and posi-
tive or negative corrective potentials are gen-
erated and applied to said control tube dependent
upon the direction of frequency correction de-
sired. Also the alternating current signals ap-
piled to the control device are balanced out in the
output so that it is not necessary to resort to
elaborate filter precautions in order to prevent
frequency modulation of the master oscillator by
either of the controlling signals.

In carrying out this invention, means are pro-
vided for comparing two wave forms and deriv-
ing from these wave forms a direct current con-
trol voltage, depending upon the relative phases
between the voltages, and using the produced di-
rect current voltage to actuate a reactance tube
for the purpose of holding one of the wave forms
in step with the other. The invention will be par-
ticularly described in connection with an em-
bedment thereof which is suitable for carrying
the 60-cycle output of a television synchronizing
generator to remain locked in to a 60-cycle power
line circuit. With this invention there is a gain in
stability so that synchronizing generators can be
reliably operated. It will be obvious that it has
other uses.

Early methods of providing a lock-in to a power
line are known. One of these is described in my
Patent 2,206,507 in which a single ended type of
detector is used to provide a direct current control
voltage for a reactance tube.

By the present invention earlier disadvantages
are overcome. For example, spurious reactions
from changes in power supply voltage and tem-
perature stability, etc., are overcome or avoided.

This invention makes use of a pair of diodes
which detect the outgoing signals in a balanced
manner, so that the central operating point for the
reactance tube 1 is that point at which the
balanced detector delivers zero output voltage and
the balanced detector is arranged so that a phase
shift of the saw tooth wave with respect to the
sine wave in one direction from this balanced
point will deliver a net positive control voltage,
while a phase shift in the other direction will
deliver a net negative control voltage. In this
way the normal operating point for the master
oscillator is such that the detector is delivering
no voltage, and any hum modulation which would
be delivered by the detector is at a minimum at
this point, thus obtaining greatest freedom from
frequency modulation of the master oscillator.

The invention may be more clearly understood
by reference to the accompanying drawings, in
which:

Fig. 1 is a schematic diagram showing the cir-
cuit of the balanced diode for comparing two
wave forms; and

Fig. 2 shows several wave forms illustrating the
principles of operation of the invention.

In Fig. 1, the double diode 6H6 has one diode
section so connected that it will deliver a negative
voltage to the output load circuit and the other
diode section so connected that it will deliver a
positive detected voltage to the output load cir-
cuit. These two voltages are arranged to buck
one another, so that the net voltage difference
between the two detected signals is delivered to
the reactance tube 1 indicated in block form after
suitable direct current filtering. The synchroniz-
ing generator 3 also shown in block form is con-
nected to a master oscillator 2 which generates a
sine wave. The oscillating frequency of this
master oscillator 2 is controlled to some extent
by the reactance tube 1. This master oscillator
2 controls a blocking oscillator or other suitable
impulse generator in the usual way, which in turn
goes through several stages of frequency division
to generate a 60-cycle sawtooth wave as indicated
by the block 4. It is therefore always a definite
sub-multiple of the master oscillator frequency.

By this invention a comparison of this 60-cycle
sawtooth wave is made with a power line 60-cycle
sine wave, or some other suitable reference fre-
cency, and a control voltage is generated to be
applied to the reactance tube 1 so that the fre-
cuency as well as the phase of the generated saw-
tooth wave will be locked in and kept locked in
with respect to this 60-cycle power line. The saw-
tooth wave is applied through the condenser 6 to
the grid 7 of the 6J5 tube, which is a balanced
phase inverter tube delivering a signal of one po-
laritv from its anode circuit through the condenser
9 to the diode plate 10 of the diode 6H6 and deliv-
ering a signal of approximately equal amplitude
but of opposite polarity from its cathode circuit
through the condenser 11 to the other diode plate
12. The variable resistors 13 and 14 are used to
balance or equalize the amplitudes of the saw-
tooth waves which are applied to the diode plates
10 and 12. Additional cathode-loaded tubes may
be inserted when desired in order to balance the
system more nearly perfectly.

The load circuits in the cathodes 15 and 16 of
the diode 6H6 are also balanced as indicated by
the resistors 11 and 18, and the condensers 19, 20 and 21.

The application of balanced sawtooth waves of opposite polarities to the two diodes and the bal-
solved load circuits in the cathodes of the diodes will cause one sawtooth wave to generate a signal at
the point 25 which is opposed by the detected signal from the other sawtooth wave. A sine wave voltage suitably isolated by the 500,000 omh
resistors 26 and 21 is inserted in a balanced man-
ner into the plates of the condenser 20 so that the diode
plates 10 and 12 are driven by a voltage wave
form which is the sum of the sawtooth and the sine
wave, and the wave forms at the diode plates will
then be of opposite polarities and consequently their
energy content in the positive excursion portion of
the cycles as the phase of the sawtooth shifts
with respect to the phase of the sine wave.

This will be more clearly understood by refer-
ence to Fig. 2, in which the section A shows the
tube wave form, and the three divisions of sec-
tion A represent three columns, the first column
showing the conditions where the sawtooth wave
form has its rapid rise occurring at the 180°
phase point of the sine wave, the second column
has the sawtooth wave rapid occurring at the 270°
phase point of the sine wave, and the third column
has the rapid rise occurring at the 360°
phase point of the sine wave.

The wave forms at B show the sawtooth waves
applied to the lower cathode circuit of the 6J5
tube to the plate 12. The amplitude ratio be-
tween the signals at A and B may be adjusted by
means of the variable resistors 13 and 14. The
wave forms at A are illustrative of the signals
that are delivered by the 60-cycle input 30 and
the transformer 31 to the conductor 32 that is
connected between the resistors 26 and 27 at one
end and the resistors 17 and 18 at the other end.

Both the wave forms A, (Fig. 2) and the wave
forms B represent the signals before mixing has
taken place. The circuits are so arranged that the
voltages are added in the respective network,
so that a summing voltage is actually applied to
the tube 10 and the plate 6H6. On Fig. 2 the wave forms designated as A+B are the wave forms which are applied to the diode
plate 12 of the diode 6H6.

These wave forms represent the signals which
are being applied to the diode before considering
the conductance of the diode. The diode passes
current, however, when the plates 10 and 12 be-
come positive with respect to the cathodes 15 and
16. When the diode is passing current a further
network of resistors 17 and 18 is shunted across
these wave forms of A+B, causing the positive
excursions of the wave forms to be attenuated or
reduced in amplitude according to the newly ap-
lplied lower impedance of the load circuit. In
practice, this simply means that the energy con-
tent of the positive excursion portion of the wave
forms of A+B as shown at A+B are the controlling factors in determining how much direct voltage is generated in the detector circuit of the cathode
load of tube 6J5.

The other diode plate 10 has a sawtooth wave
form applied to it from the upper or plate

circuit of the 6J5 tube, which is represented by the
diagrams at C of Fig. 2, which, by mixing with
the wave forms A in the three phases mentioned,
result in the three wave forms shown at A+C in
Fig. 2.

The diode plate 12 has its cathode 16 grounded,
and therefore develops its detected signal essen-
tially as a plate output diode, the rectified volt-
age appearing across the resistor 27 through the
transformer secondary 31 and across the resistor
18 to ground. When the plate 12 of the diode
6H6 draws current with respect to the cathode 14,
this plate draws charge from the condenser 20 so
that the point 30 becomes negative with respect
to ground, thus preventing momentarily any fur-
ther flow of current in this diode. When the wave
form of A+B again returns to its negative
portion this condenser 20 will hold a negative
charge for a time so that the diode action.
On the other hand, the diode 10—15 is
connected with part of its effective load circuit
in the plate 10 network and part of the effective
load circuit in its cathode 15 network, so that
when the plate 10 starts to conduct, the cathode
15 will become positive with respect to the point
30, developing a voltage across the resistor 17
which is returned by the action of the condenser
19. The resistors 17 and 18 are connected in
series, so that these opposing voltages are added
to one another, and whichever voltage is the
larger will determine the net voltage delivered to
the condenser 25 and on through the filtering
stages 26 to the reactance tube 1.

Therefore the diode 12—16 as connected tends
to deliver a negative signal derived from the wave
forms A+C to the point 30, and thence to the
reactance tube 1. The diode 10—15 tends to deliver a positive signal derived from the wave
forms A-C to the point 30, and thence to the
reactance tube 1. By a comparison of the wave
forms A+B at the three phase relations plotted
with the wave forms A+C at the corresponding
phase positions, it can be seen that the positive
energy in the wave form designated by reference
character 40 (Fig. 2, A+B) is approximately the
same as the positive energy shown in the cross-
hatched region of the wave form designated by
reference character 51. The reversal in shape of
the wave forms is not serious, since the diode
detectors have a low frequency detecting filter in
their cathode circuits and the output load re-
sponds essentially to the energy in these wave
forms. But the wave form of reference character
41 contains more energy in its positive portion
than the wave form 40, and the wave form 50 at
this same phase relation contains less energy
than the wave form 51. Since wave form 41
delivers a negative detected signal and wave
form 50 delivers a positive detected signal, it can
be seen that at the phase relation of 180° the	negative detected signal will predominate in
magnitude, and a net negative voltage will be di-
ivered to the terminal 30 (Fig. 1). This negative
voltage, applied to the reactance tube 1, tends
to slow down the master oscillator 2, causing the
sawtooth wave to tend to shift back toward the
270° phase point.

On the other hand, if the master oscillator 2 is
running too slowly, the phase relation of the saw-
tooth with respect to the sine wave may be, as
illustrated (right hand voltages of Fig. 1) and
360°. In this case the energy in the positive
cross-hatched portion of 52 is seen to be larger
than the energy in the positive cross-hatched
town of 42, and the diode 10—15, to which the
wave form of A-C is fed, will deliver positive
control signal which predominates in magnitude
and thus increases the master oscillator frequency
momentarily, causing the phase of the sawtooth
wave to shift back toward the 270° point to an
intermediate phase angle which is the position of
equilibrium.

If the master oscillator 2 is on the correct fre-
frequency which can be determined by closing the switch 33, then opening the switch 33 will connect the balanced detector control circuit and the sawtooth wave will beat against the sine wave thus generating a control voltage which will shift the master oscillator frequency until the phase relation is at the low stable point. This point corresponds to the 270° diagram, Fig. 2, where it can be seen at once that the positive cross-hatched energy of wave form A (Fig. 2, A+B) is equivalent to the positive cross-hatched energy of wave form B (Fig. 2, A+C), and therefore the output net voltage will be neither positive nor negative and will be balanced for control voltage, and furthermore will be balanced for any surgevoltages from power supplies or from other voltages which might otherwise get on through the integrating filter.

There will be another condition in which the wave form of A+B (Fig. 2) in its positive portion will have the same energy as the wave form A+C in its positive portion, but this other condition is at a phase relation such that the detected voltage will tend to throw the frequency farther off the correct value rather than toward its correct value. With this circuit it is found that the master oscillator may be held in step over a phase relation from 180° to 360° of the sine wave.

This is adequate for most applications, but in some cases it may be desirable to cause the 60-cycle sine wave from the power line to control directly a sawtooth wave form and then utilize the same balanced detector circuit to compare the power line sawtooth with the synchronizing generator sawtooth, thus making it possible to find a stable control point for phase angles essentially anywhere within the 360°, as can be done with this invention.

The principles of this balanced detector circuit can be used for comparing other types of wave forms with one another for control purposes, such as locking-in the switch oscillators of a television receiver with respect to incoming synchronizing pulses or for controlling the oscillator of a frequency modulated transmitter with reference to a crystal oscillator.

While specific values are shown on the circuit diagram, it is well understood that the principles of operation of the circuit are not confined to any specific input signal amplitudes, and the values of the circuit components may be changed very widely and still yield satisfactory performance.

What is claimed is:
1. A synchronizer for an oscillator, comprising two diodes, means for applying impulses in phase opposition from said oscillator to the anodes of said diodes, and means to apply low frequency since wave impulses in parallel between the plates and cathodes of said diodes, one of said cathodes being connected to ground and the other one to said oscillator.
2. The device of claim 1, in which resistors are connected in series between said anodes.
3. The device of claim 1, in which resistors are connected in series between said cathodes.
4. The device of claim 1, in which two resistors are connected in series between the anodes of said diodes and two capacitors are connected in series between the cathodes of said diodes.
5. The device of claim 1, in which two resistors are connected in series between the anodes of said diodes and two capacitors are connected in series between the cathodes of said diodes and two resistors in series are connected in parallel with said capacitors.
6. The device of claim 1, in which a capacitor is connected between said other one of said cathodes and ground.
7. In a synchronizer for an oscillator, a balanced phase inverter comprising a vacuum tube having its grid connected to said oscillator, diodes having their plates connected respectively to opposite sides of said inverter whereby signals from said oscillator are connected in phase opposition to said diodes, one of said diodes having its cathode grounded, balanced load circuits connected to the cathodes of said diodes, means to apply a low frequency sine wave voltage in phase to the plates of said diodes, and a connection from said balanced load circuits to said oscillator whereby the frequency of said oscillator is controlled.

RICHARD L. CAMPBELL