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CRYSTAL OSCILLATOR HAVING FREQUENCY PROPORTIONAL
TO VARIATIONS OF AN ELECTRICAL LOAD
Filed April 17, 1961 4 Sheets-Sheet 1

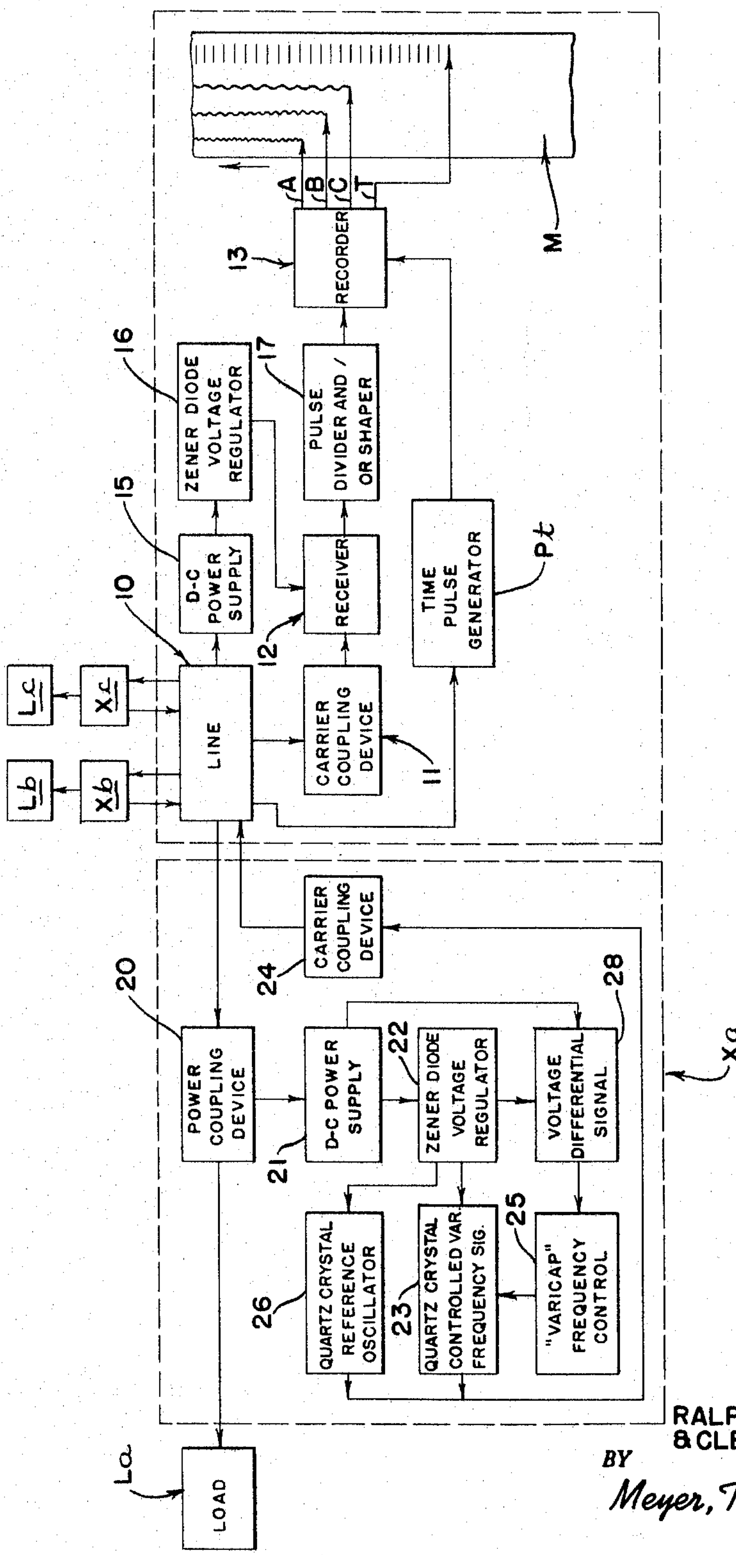


FIG. I

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Filed April 17, 1961 4 Sheets-Sheet 2

FIG. 2

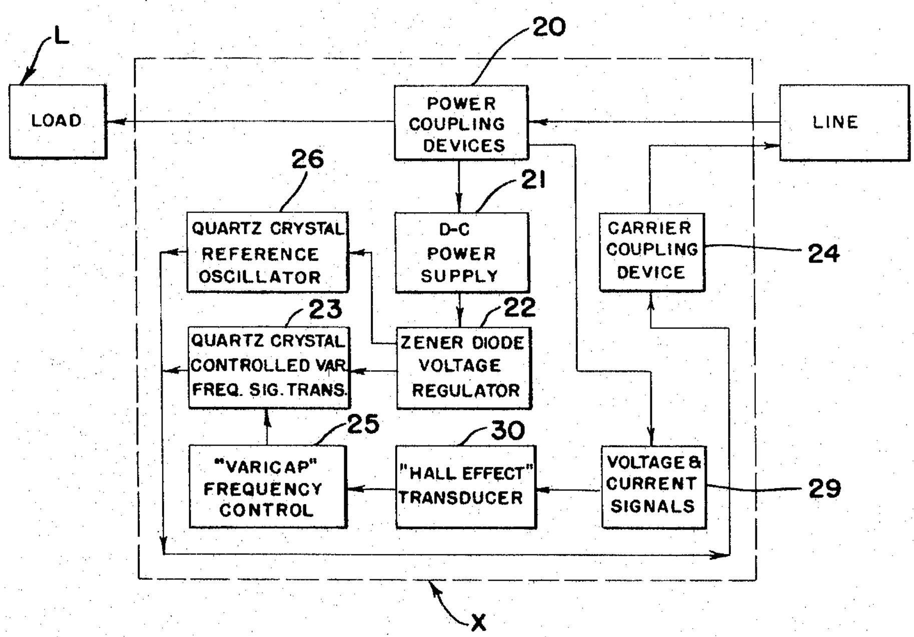


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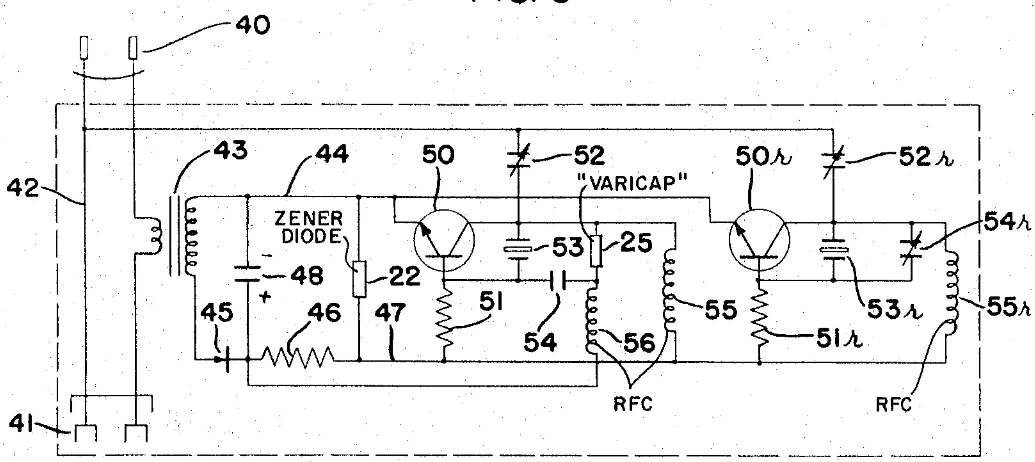
FIG. 3



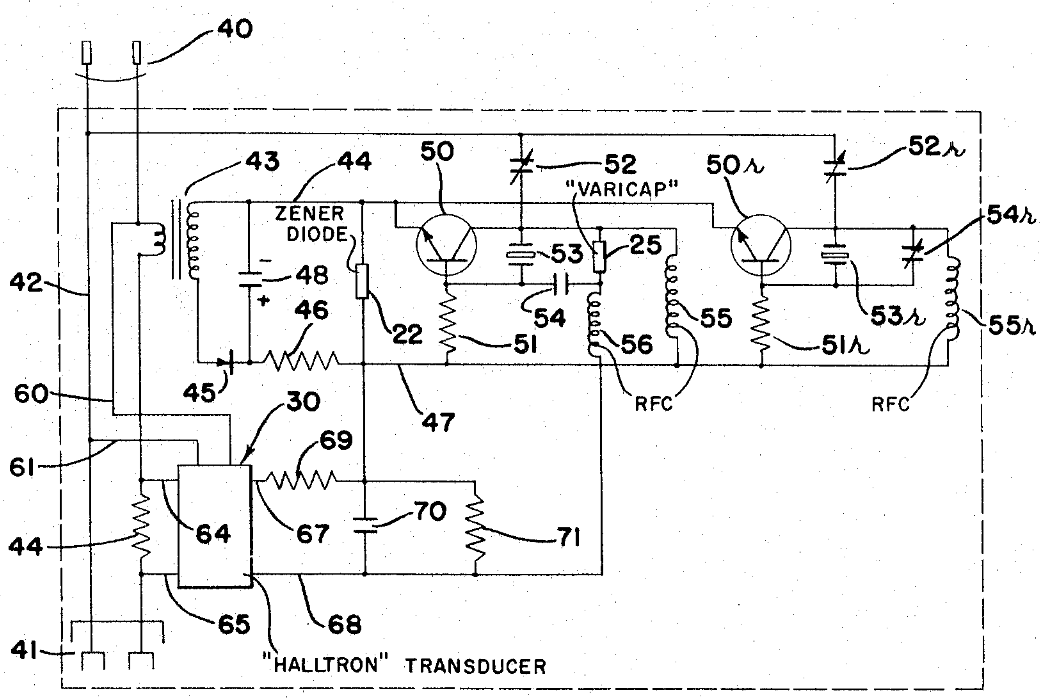




FIG. 4

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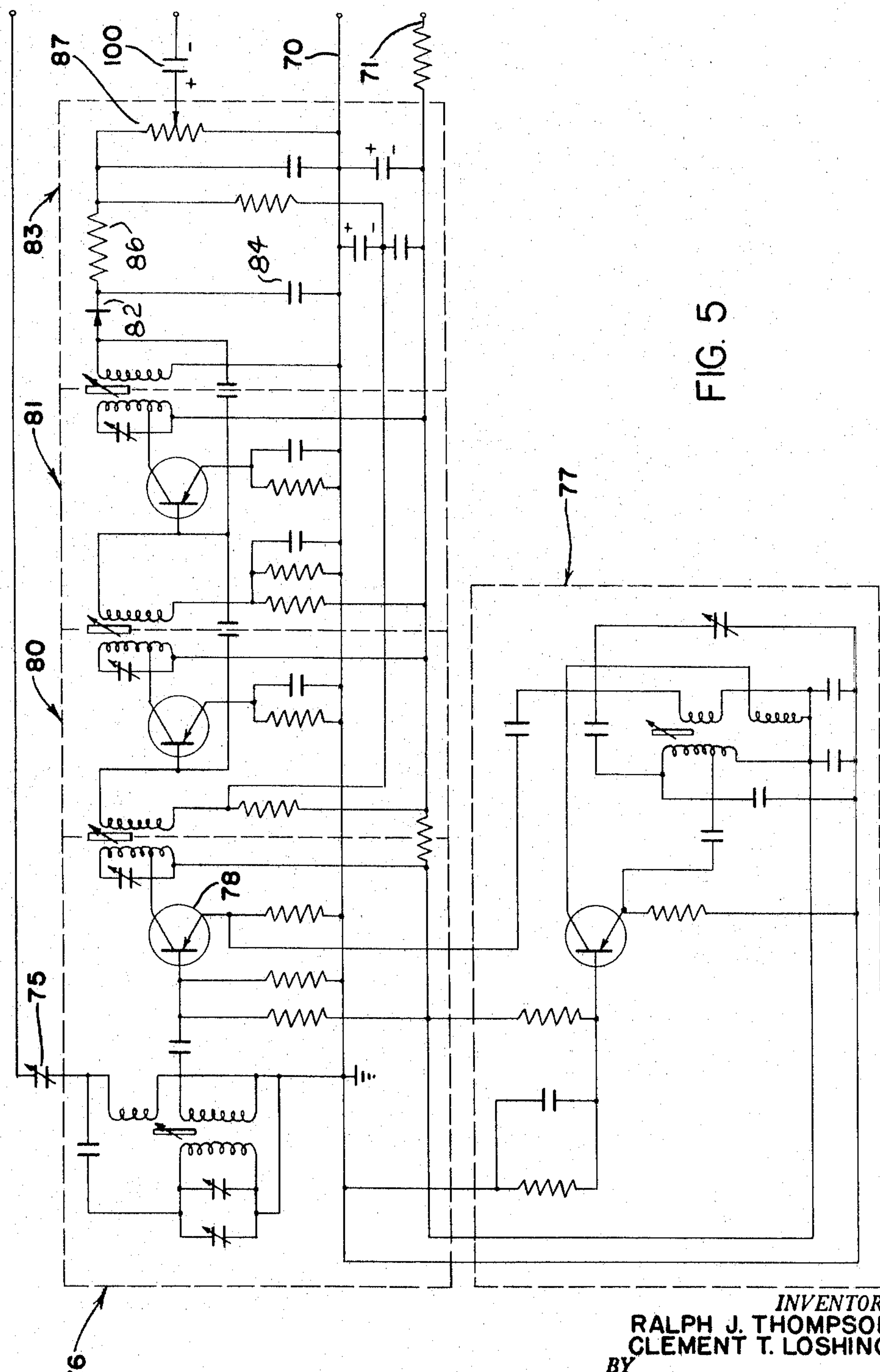


FIG. 5


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3,297,956

# CRYSTAL OSCILLATOR HAVING FREQUENCY PROPORTIONAL TO VARIATIONS OF AN ELECTRICAL LOAD

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Original application Apr. 17, 1961, Ser. No. 103,309, now Patent No. 3,135,573, dated June 2, 1964. Divided and this application Aug. 28, 1963, Ser. No. 309,913
5 Claims. (Cl. 331—177)

This application is a division of application Serial No. 103,309, filed April 17, 1961, now United States Patent No. 3,135,573, issued June 2, 1964.

The present invention is concerned generally with a data gathering, transmitting and recording system. More especially it is concerned with such a system, method and means, in which at one or more stations there is monitored a respective variable in an event which may there occur, with the variable being sensed and applied in a transmitter to provide a transmitter signal varying in frequency from a respective distinct base frequency. Each such signal is received at a central recording station and transformed into a signal representative of the variable monitored and adapted for recording on a medium such as magnetic tape where several longitudinal channels of information may be imposed.

Particularly the present invention is concerned with a system for sensing at each station an event involving a variable, which event brings into operation a transmitter producing a signal in frequency varying proportionately to the variable and sent by low level electro-magnetic radiation or by carrier current transmission to a relatively remote receiving and recording point. The invention is disclosed in the specific form of a carrier current system adapted for electric utility load studies, wherein it is desired to record on a medium suitable for processing in modern computing machines, data respecting load demands continually over successive periods throughout household, manufacturing establishment, or other premises of a utility consumer. Transmitter circuitry is disclosed adapted to incorporation in small, inconspicuous rugged units. The units may be of a size permitting them to assume a form plugged or screwed into a receptacle or socket and in turn receiving the power cord plug, or a load device itself such as a lamp bulb; or a form readily installed even in existing switch boxes, fixtures or receptacles.

At the recording station, receiver means for each transmitter provides an audio range output signal upon operation of a respective transmiter, which output either directly, or after modification as by pulse-shaping or frequency dividing means, is applied through a corresponding recorder head section to a medium such as magnetic tape. The frequency variation of the recorded signal, being at least of known proportion to the transmitter frequency variation, is then a continuous record of the actual instantaneous load at the transmitter. Moreover, with locally generated time pulses applied in a time channel on the tape, the record produced is especially useful for data processing by a data translating system such as that of our U.S. Patent 2,960,266.

The invention is of course useful in other fields beyond that here specifically disclosed. Thus where a device comes into operation effecting a voltage change which is linearly related to a variable in the event to be monitored or observed, a transmiter is brought into operation, and by the present invention an output signal of the transmitter is varied from its specific base frequency proportional to the voltage, and hence the variable. Alternatively, if the occurrence of an event at a transmitting monitor station produces an energy effect, the effect can be sensed through



an appropriate transducer providing an output voltage effective to vary the frequency of a transmitter signal, the variation in frequency being proportional to a rate involved in the observed event.

A system and means for obtaining the above-described objects and advantages are set forth in the following description and drawings, representing the invention as applied to electric utility load studies, wherein:

FIG. 1 is a block diagram for one embodiment of the system invention including a detailed block sub-diagram *Xa* for a "volt-ampere" type transmitter which may be used for one or more measured loads;

FIG. 2 is a block diagram for an "actual or true power" type transmitter which may be used for one or more measured loads;

FIGS. 3 and 4 are schematic diagrams of circuitry which may be used, especially where miniaturization is desired, respectively for transmitters as shown in the detailed block diagrams of *Xa* and X in FIGS. 1 and 2;

FIG. 5 is a schematic diagram for a receiver suitable for the system and adapted to compact or miniaturized construction.

In FIG. 1 there is represented by a block diagram one embodiment of the system invention, wherein a plurality of loads *La*, *Lb* and *Lc*, on a line **10** of a local or general electrical power distribution system, by respective operation actuate corresponding transmitters *Xa*, *Xb*, *Xc* to generate signals here coupled to and by carrier current transmitted through the line **10** to a common receiving and recording point; at which point the signals are coupled through coupling device **11** to receiving means **12** the output of which is fed to recorder means **13** as later described for applying to a record medium, such as a magnetic tape M, in respective parallel channels, A, B, C, a load record for each transmitter. Preferaby, there is also applied to the record medium in a time channel T time pulses locally generated at a constant time rate by time pulse generating means *Pt*. The transmitters, upon operation of their respective loads, each generate variable frequency signals, having distinct non-interfering base frequencies, representative in frequency variation of the loads as metered.

The transmitters in the disclosed system, individually considered may be either of the "volt-ampere" type (of which a specific embodiment is disclosed in *Xa* of FIG. 1 and in more detailed and specific form in FIG. 3) or of the "actual" or "true" power type (of which a specific embodiment is disclosed in X of FIG. 2 and in more detailed and specific form in FIG. 4). Either form of transmitter generates a signal of variable frequency, with the variation in frequency a function of some variable characteristic of the load. The frequency variation, for example, may be a function of I or $I \cos \theta$; that is, with the line voltage being taken as constant, apparent or true power respectively. For any load the type of transmitter is selected as may be required for the desired character, degree, or precision of measurement.

Thus *Xa*, *Xb*, *Xc* may transmit with respective base frequencies of 5,000,000, 5,300,000 and 5,800,000 c.p.s., signals instantaneously varying from the individual base by a frequency difference which is a function of the load at each.

At the recording end of the system represented in FIG. 1, there is further shown a D.C. power supply means **15** and Zener diode type voltage regulator means **16** for energizing the receiver means from line **10**; and pulse dividing and/or shaping means **17** between the receiver means **12** and recorder means **13**. The receiver means **12** includes for each load signal transmitter either a separate receiver network or channel circuit in a single receiver providing a distinct output corresponding to each transmitter, or a separate receiver unit providing a separate receiving channel. In either case, if required or advantageous in a particular situation, the pulse dividing and/or shaping means 17 may provide for one or more output channels of the receiver means a corresponding pulse shaping and/or dividing circuit for applying to the recording medium M through a respective head section of the recorder means 13 a respective trace or record. Such a pulse dividing circuit is of utility for any channel where an acceptable tape speed would result in an undesirably high linear rate of recorded pulses.

In the overall form of the system as here disclosed, it is contemplated that each load will be connected to the supply line 10 by power coupling means 20 associated with a respective transmitter or incorporated in a physical unit embodying the transmitter, the means 20 then providing power conduction to the load and also providing power for energizing the transmitter as through D.C. power supply means 21 and the preferably included Zener diode type voltage regulator 22 to a crystal controlled variable frequency oscillator 23, the output of which is fed through a suitable carrier coupling device 24 into the line.

The frequency variation of the oscillator is accomplished through the separately represented oscillator frequency control means 25 such as the solid state device currently known under the trademark "Varicap," for which the instantaneous capacity as an output is determined by and proportional to an applied or input voltage. The load is then sensed through the power coupling means 20 and a corresponding voltage is developed for aplication to the "Varicap" frequency control means 25, as hereinafter detailed. Either the current drawn by the load is reflected through the D.C. voltage supply 21 and an associated voltage differential signal producing means 28 (see FIGS. 1 and 3); or through power coupling means 20 and voltage and current signal producing means 29, and a transducer means 30 such as a "Halltron" transducer circuit (see FIGS. 2 and 4).

In either case, as a load comes on the line, the respective transmitter is energized to come into operation; and as the load varies, developing a voltage change applied as an "input" to the "Varicap," the corresponding variation of the transmitter frequency determining capacitance produces a frequency variation proportional to the selected load characteristic variation.

A crystal controlled reference oscillator 26 advantageously is used in the system at either the receiver or transmitter points to cancel the effect of ambient conditions such as temperature, preferably as shown in the drawings at each transmitter point, where it is also energized by the D.C. power supply through the voltage regulator 22. The voltage to both the reference oscillator 26 and the variable frequency oscillator 23 is maintained at a fixed value by the Zener diode 22 and resistor 46 so that no frequency variation, relative or obsolute, is introduced by voltage changes to either oscillator. Both quartz crystals 53 and 53*r* are of the same cut and are in the same ambient temperature location, usually coadjacent, so that no relative frequency changes will occur. Therefore, the only variable that will change the relative frequency of the two oscillators is the capacitance of "Varicap" frequency control means 25, which thereby varies the relative frequency of the two quartz crystal oscillators in compliance with the controlling voltage signal.

With the disclosed system variable frequency signals transmitted over a common medium, here by carrier current transmission through the line, and received by the receiver means 12, produce in respective receiver channels audio range variable frequency outputs which are at least individually proportional to the respective metered load characteristics. The audio range outputs of a given receiver means channel may, for particular circumstances of a specific recorder and desired speed of the recording



medium, such as a tape, require pulse shaping and/or output pulse frequency division. Suitable means for division are now well known, for example, the "Type 502 Solid Circuit Network" of Texas Instruments, Incorporated, connected as a binary counter, a miniaturized component having a stated 200 kc. upper limit (e.g., see "Electronics," July 29, 1960, issue); or a magnetic core frequency divider, as described in Electronics, April 11, 1958, issue; or a tunnel diode frequency divider, as described in data sheets of Hoffman Electronics Corporation, Semiconductor Division; or, e.g., Sprague Type 73Z1 Core-Transistor Diode Counters, cascaded if needed.

Conveivably as said receiving means, a quite wide band receiver unit might be used to receive and amplify all transmitted signals as a composite output (with or without conversion into lower frequency) having components each with a frequency variation proportion to a metered load characteristic and with the composite output then being applied to a filter of said receiver means including separate channels each adapted to pass a band of the receiver unit output corresponding to a particular transmitter, and with a beat frequency oscillator signal for each filter section output mixed therewith to provide (through pulse shaping and/or dividing means) a final signal to a recording head section proportional in frequency to the metered load characteristic.

However, for ultimate simplicity or convenience of design, it is often preferable to use at the central receiving station individual receiver units for each channel, i.e. for each transmitter, which are coupled to line and tuned to the frequency range of respective transmitters to apply (through pulse shaping and/or divider units where used) to the recorder, individual outputs in the audio range proportional to the metered load characteristics.

The latter arrangement is hereinafter described wherein the receiver means 12 includes for each transmitter the general arrangement of FIG. 5.

In any event with a system as thus far generally detailed, there is producible on one medium a multi-channel recording of monitored events or metered variables such as individual loads of electric energy consuming devices, with a time channel record of time pulses generated at pre-set rate, whereby the records in the several channels may be related to time of occurrence with the actual time of the beginning or end of the record known; or interpreted as functions of time such as instantaneous time rates; or in effect integrated over selected periods, as contemplated in our Patent 2,960,266. From the known characteristics of each transmitter and the known frequency division ratio, appropriate meter constants are available for each record channel upon processing the data there recorded. The presence of the time channel in the record is especially advantageous for such purposes, inasmuch as it provides a means for rendering the playback interpretation of recorded data independent of differences in recording and playback tape speeds.

Considering now in further detail suitable transmitter devices for the general system, FIG. 3 presents in schematic form circuitry adapted for a miniaturized, compact, inconspicuous and rugged device, which transmits upon operation of a load a signal having a frequency variation which is proportional to an instantaneous "volt-ampere" demand of the load; it being contemplated that the device will assume the form say of a plug-in unit having a casing with a plug 40 and socket 41 respectively adapted to be inserted into a receptacle or outlet of an electrical A.C. power distribution system and to receive the plug of an electrical device forming an applicable load on the power system.

For coupling of the load to the power system, the source of electrical energy, the said plug and socket are connected on one side by the conductor 42; and on the other through the relatively low impedance, here shown as the primary of a transformer 43, in view of the prevalence of A.C. power, although a low value resistance could be used (for a D.C. line) across which a voltage drop is utilized to provide the power coupling and D.C. supply. The transformer **43** provides power coupling from the line for energizing the transmitter, so that the specific circuitry thus far described is represented by the power coupling device block **20** of FIG. 1. The D.C. power supply represented by block **21** of FIG. 1 includes the negative conductor **44** connected to one said of the transformer secondary; the secondary in series with the rectifier diode **45** and the resistor **46** to positive conductor **47**; and the filter or D.C. smoothing capacitor **48** connected from **44** to a point between **45** and **46**; while the voltage regulator **22** of FIG. 1 appears as the Zener diode **22** connected between **44** and **47**.

For producing a signal of varying frequency there is providing the transistorized oscillator circuit comprising a transistor **50** having emitter connected to the negative side **44** of the power supply and base connected to the positive side through bias resistor **51**; and a frequency determining tank network, coupled from the collector through variable capacitor **52** (as the line coupling device **24** of FIG. 1) to conductor **42**. The tank circuit includes the crystal **53**, e.g., a quartz crystal, between the collector and base; and a solid state device **25** (such as a "Varicap," as described for FIG. 1) and a blocking capacitor **54** in series between base and collector (i.e., in parallel with **53**). The positive side of the voltage supply is applied through RF choke **55** to the crystal. To the device **25** there is applied through the RF choke coil **56** as hereinafter described a potential causing a variation in the capacity of the solid state device **25** and therefore of the oscillator frequency. The chokes **55, 56** serve respectively to apply D.C. voltage to crystal **53** and device **25** while chocking any RF leakage back into the power supply, and also through **55** to apply transistor operating voltage.

A reference oscillator, for the individual transmitter, which may be either at the individual receiver unit or at the transmitter, is here shown (as at block **26**, FIG. 1) in preferred location at the transmitter, with a configuration analogous to that of the variable frequency oscillator and similarly connected as appears in the drawing to the power supply leads **44, 47** and coupled through adjustable capacitor **52***r* to the line. In the reference oscillator circuit the analogous components, designated by like reference numerals with suffixed "*r*", are transistor **50***r*, quartz crystal **53***r*, choke **55***r*, resistor **51***r* and vernier adjustable capacitor **54***r*, the latter actually being opertively set (within small limits) to correspond to the desired base frequency of the variable frequency oscillator circuit, analogous to the net capacitance of **54** and **25** at zero load condition, and permit adjustment for slight deviation of the fundamental crystal frequency.

At this point should be noted the similarity of FIG. 4 circuitry to that thus far described for FIG. 3, for which reason like reference numerals are used for analogous components. The Zener diode **22** in FIG. 4 operates essentially only as a voltage regulator for the power supply of the oscillators.

In FIG. 3 the point between diode **45** and resistor **46** is connected through RF choke coil **56** to one end of device **25**, to use **46** in conjunction with the secondary of transformer **43** as the differential signal generating means **28** of FIG. 1; and the Zener diode has a further function of holding the voltage drop variation (therefore the potential variation effective on device **25**) only to that occuring across resistor **46**. In FIG. 3 the variation of instantaneous load current through the primary of transformer **43**, reflected in the secondary, is effective to produce across resistor **46** (as the means **28**, FIG. 1, for developing the voltage differential signal) a variable potential drop applied across device **25** for varying its capacitance and therefore the frequency of the oscillator signal. The transformer **43** for FIG. 3 or 4 is designed



for the lowest load which will produce the rated Zener diode voltage.

In FIG. 4, the coupling of the load to the power line on the one side involves the series connected primary of transformer **43**, and the current input branch to "Halltron" device **30**, that is, the "shunt" resistor **44**. The Hall-effect transducer **30**, may, for example, be one such as that described in a prior publication of Ohio Semiconductors, Inc., for the therein denominated "Halltron HS-51" solid state device, among other applications shown for an instantaneous power meter. For such application, (as means **29**, FIG. 1, for producing voltage and current signals) preferably the line side of the said transformer primary and the conductor **42** are connected to a magnetic input of the transducer, as by leads **60, 61**, that is, to an electromagnetic field producing component, which provides a field intensity substantially proportionate to the voltage applied to the load; and the current input to the load through conductor **42**, ultimately returning from the load on the other side of socket **41** through resistor **44** shunting the transducer current input is applied at leads **64, 65** to the transducer for producing in transducer output across **67, 68**.

The net effect is that the output of the transducer is applied through RF choke coil **56** to the device **25** over the signal averaging network (between coil **56** and positive supply lead **47**) comprising resistor **69** connected to positive supply lead **47**, and the capacitor **70** and resistor **71** connected in parallel between **47** and the output lead **68** to **56**.

The circuitry here described then results in a frequency variation (due to potential applied across device **25**) which is a linear function of the voltage output of the averaging network, in turn proportional to the "actual" or "true" power demand.

Returning then to the receiver station, FIG. 5 presents circuitry for separate receivers for each transmitter, thereby providing distinct channels from the line adapted to provide outputs to respective recording head sections for record channels A, B, C, etc. through corresponding sections of or through distinct dividing and/or pulse shaping means **17** as previously described. FIG. 5 actually shows the adjustable capacitance **75** (as the coupling device **11**, in FIG. 1) feeding signals from the line into a completely transistorized receiver unit (as a part of means **12** of FIG. 1), the receiver unit being energized from a common D.C. supply indicated by leads **70, 71**.

The band tuned input mixer section **76** including transistor **78** passes the signal of a corresponding transmitter for mixing with the output of a beat frequency oscillator section **77** to produce a lower frequency range signal applied through two transistorized IF amplifier stages **80, 81** to the detector diode section **83** including diode **82**. The output of diode **82** (by-passed for the IF base frequency through capacitor **84** to lead **70**) is developed across fixed resistor **86** and the winding of output level adjusting potentiometer **87** in series between diode **82** and the positive power supply lead **70**. The receiver output is coupled through the arm of potentiometer **87** and coupling or D.C. isolation capacitor **100** to the subsequent pulse-shaping and/or dividing means as described for **17**.

By way of example, where the unit of FIG. 5 corresponds to a transmitter having a 5 mc. base frequency, the input circuit of the mixer section is tuned to pass a band range of 5 mc. plus the maximum frequency variation to be expected at the transmitter; and with the BFO section **77** having a 4.6 mc. output to the mixer there results an amplified output of IF stages **76, 77** having an actual frequency varied from an intermediate base frequency of 0.4 mc. by the variation in the corresponding transmitter signal. This output applied through detector diode stage **83** and associated circuitry where the 0.4 mc. base component is by-passed results in an amplified output across the resistor of output level adjusting potentiometer

87 having an audio frequency corresponding to the frequency variation developed at the corresponding transmitter. Pulse shaping actually begins at diode 82.

Although it is perhaps obvious, it is remarked that the undulate traces appearing in the tape load recording channels are merely visual symbols of pulse records invisible in the case of magnetic tape, nor do such symbolic traces necessarily represent even graphically the final pulse shapes as magnetically recorded.

We claim:

**1.** A transmitter for transmitting data from one point to another by means of an output signal having a frequency variation proportional to an electrical variation occurring at an electrical load with respect to which data is to be transmitted, comprising:

a pair of conductors having means at opposing ends for connecting said load across an alternating current voltage source;

a transformer having a primary winding and a secondary winding, said primary winding connected in series circuit with one of said conductors;

direct current voltage supply means having an input circuit and an output circuit, said input circuit connected across said secondary winding for developing direct current voltage;

a crystal controlled oscillator connected across the output circuit of said supply means and including a solid state device of variable capacitance for varying the oscillator output frequency, said device being responsive in capacitance to variations in electrical potentials applied thereto; and,

means coupled with at least one of said transformer windings and responsive to said electrical variations occurring at said electrical load for applying an electrical potential, varying in proportion to said electrical variations, to said device whereby the output signal of said oscillator will exhibit frequency variations proportional to said electrical variations.



**2.** A transmitter as set forth in claim **1** wherein said last named means includes a resistor connected to the secondary winding of said transformer in such a manner that an electrical potential is developed across the resistor proportional to an electrical potential across said load, and means coupling said resistor with said device so that a corresponding potential is applied across said device.

**3.** A transmitter as set forth in claim **2** wherein said coupling means includes a radio frequency choke.

**4.** A transmitter as set forth in claim **1** including a second crystal controlled oscillator connected in parallel with said first oscillator, and output circuit means connecting said oscillators with the other of said two conductors.

**5.** A transmitter as set forth in claim **1** wherein said last named means includes a "Hall effect" transducer having a first input circuit connected across said pair of conductors, a second input circuit connected across a resistor in series circuit with said primary winding, and an output circuit; and means coupling said output circuit with said device.


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