Sept. 8, 1959 A. NYMAN ET AL 2,903,204

HEAT SEEKER WITH PROPORTIONAL CONTROL

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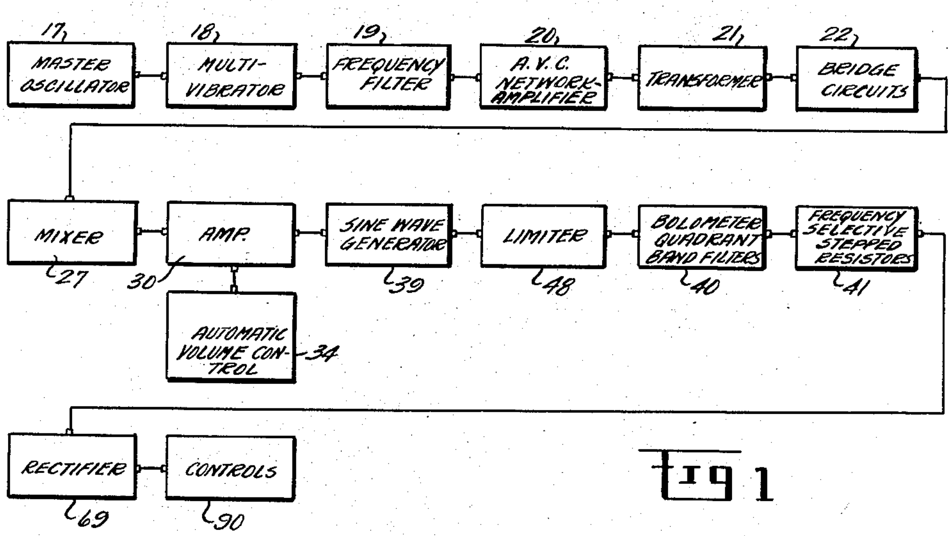

Fig 1

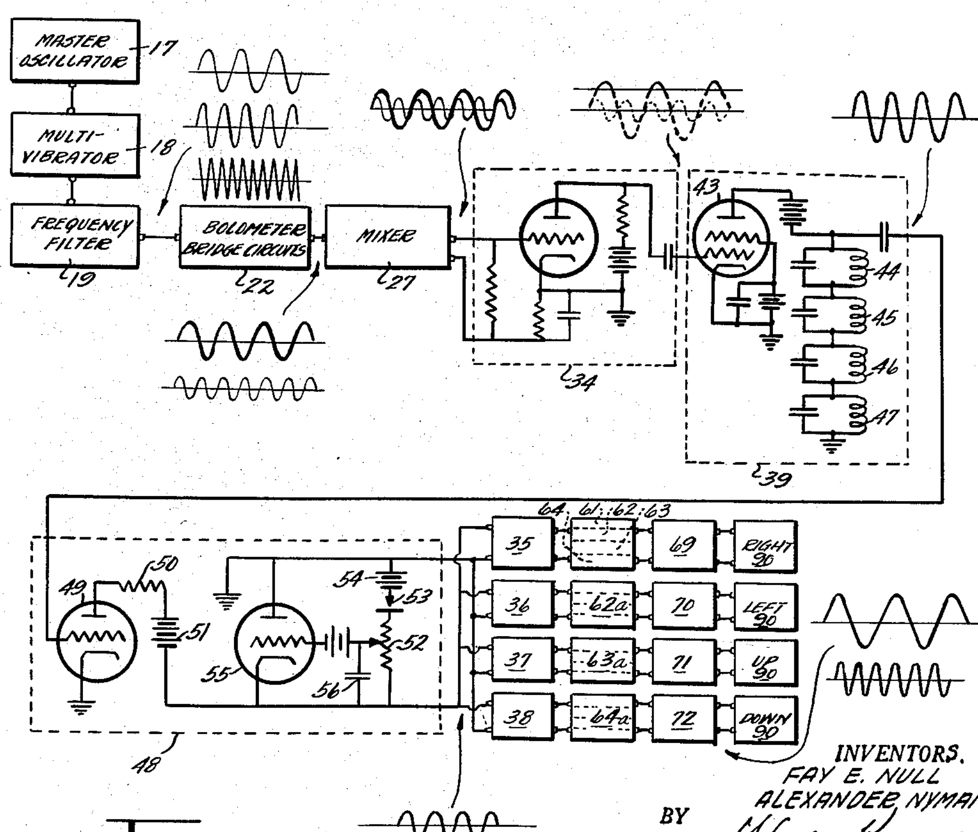

Fig 2

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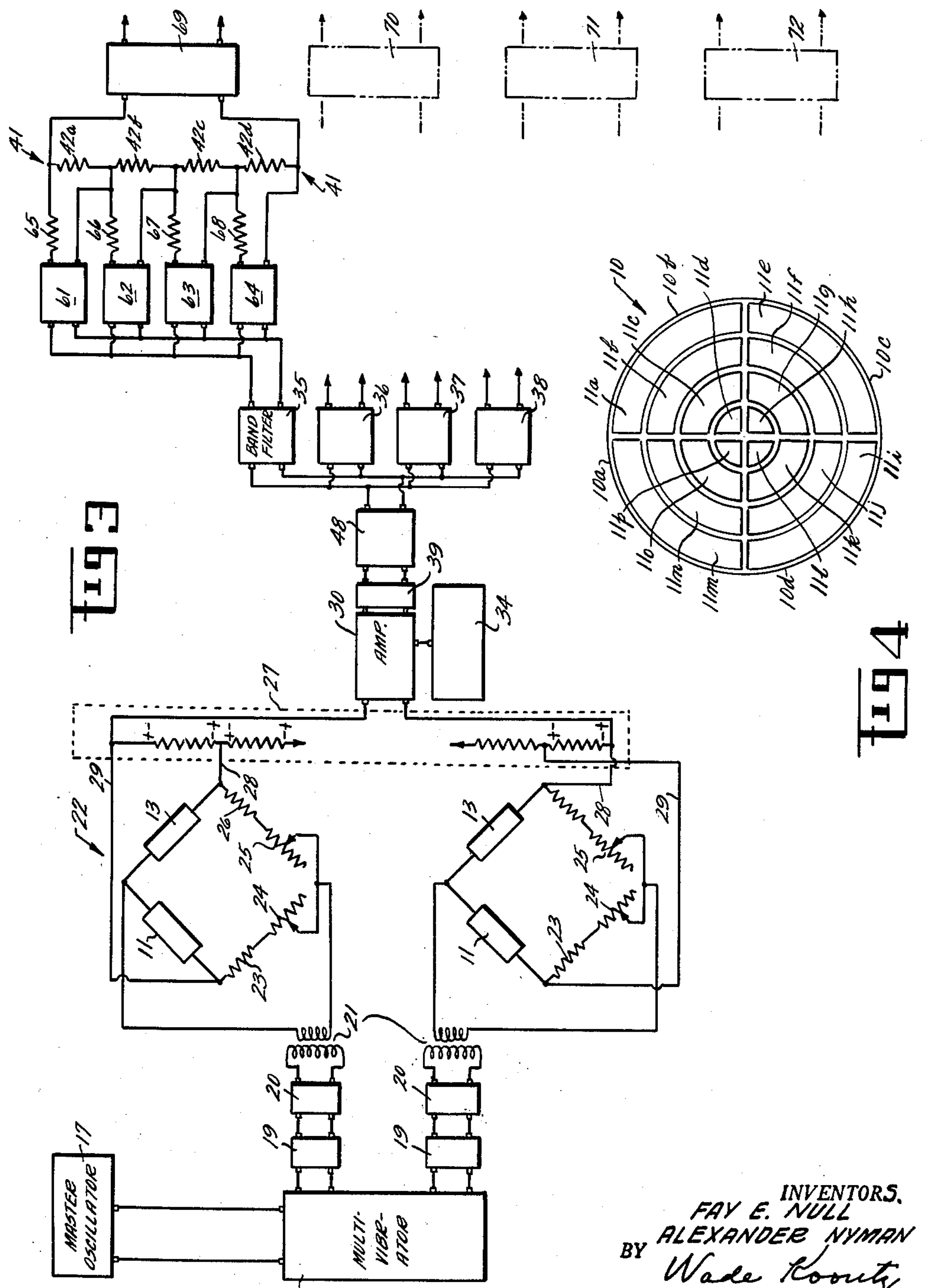

Fig 3

Fig 4

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HEAT SEEKER WITH PROPORTIONAL CONTROL

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Fig 6

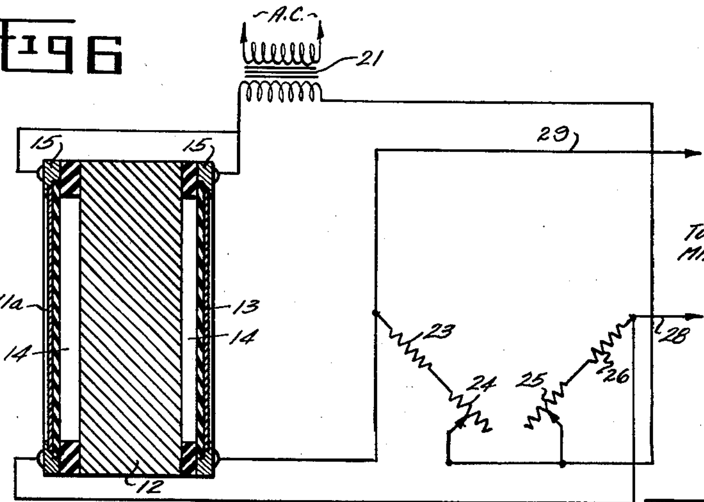


Fig 5

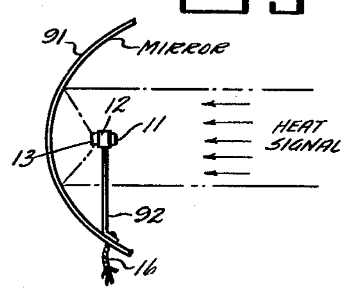


Fig 7

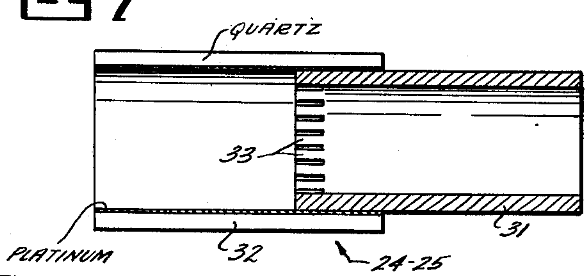


Fig 8

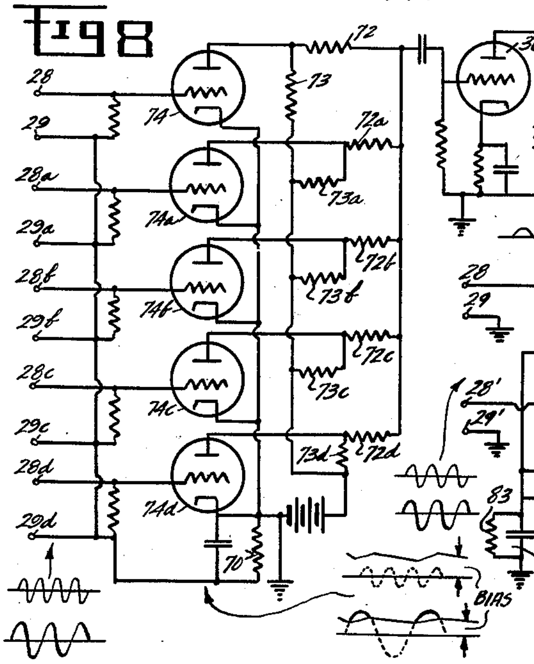
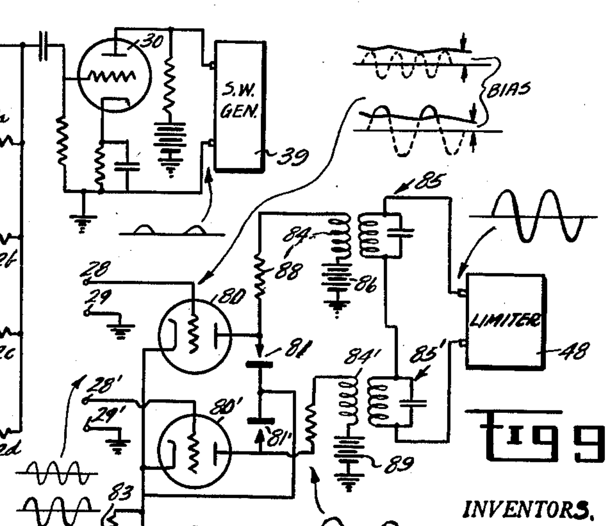


Fig 9



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United States Patent Office

2,903,204

Patented Sept. 8, 1959

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HEAT SEEKER WITH PROPORTIONAL CONTROL

Alexander Nyman, Dover, Mass., and Fay E. Null, Dayton, Ohio

Application November 8, 1946, Serial No. 708,562

10 Claims. (Cl. 244—14)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to us of any royalty thereon.

This invention relates to heat seekers and more particularly to a device used to direct guide missiles to military targets which are giving out heat, or to a similar use.

In the past, devices of the type here considered were characterized by serious limitations in attempting:

To distinguish target radiation from background radiation at long distances, as for example, five miles or more;

To provide a quickly responding system, and

To provide control of the system in a degree that is proportional to the deviation of the received signal from a predetermined direction as distinguished from the "all or none" type of control in which every signal causes the same control surface movement.

There are at present two kinds of systems commonly employed.

A continuous observation system in which heat sensitive elements or bolometers are arranged in multiple in a circular bank divided into quadrants. Each quadrant is provided with its own path for transmitting a received signal to the control of a missile and the control is actuated by the signal to direct the missile toward the target, depending upon from which particular quadrant the strongest signal comes.

A system in which the field of view is scanned by a to-and-fro or circular motion so that successive portions of the field of view fall upon the detecting element in sequence. Directional sense is obtained by commutation of the detector output as the scanning spot passes from one quadrant of the field of view to the next quadrant.

The present invention belongs to the first class of such systems. The invention employs a plurality of radially disposed bolometers arranged in each quadrant of a preferably circular bank and may employ as many control circuits as there are bolometers.

One object of this invention is to provide an improved heat seeker arrangement by means of which the response of the heat detector will actuate the control system of a guided missile upon which it is mounted, with regard to two primary facts: (1) the position of the target with reference to the optical axis of the target seeker (i.e., whether the target is up or down, and right, or left of this axis). This fact will determine which control of the guided missile is to be actuated from a missile-carrying airplane and in which sense, in order to direct the missile to the target, and (2) the angular deviation of a line from the target seeker to the target with reference to the optical axis of the target seeker. The latter fact is used to determine the amount or rate of control to be applied to the guided missile to restore it most effectively to a desired flight path. Flight path control over the missile is best accomplished by proportional control which has certain well known advantages over the unproportional or flicker control which alters the flight path of the missile by a fixed amount.

Advantages of the improved seeker—Proportional control

The improved seeker has the advantage of proportional control, whereby each bolometer in the receiver image area gives rise to a signal having its individual frequency, thereby providing an output signal, the magnitude of which is proportional to the distance of the bolometer from the center of the bolometer bank or image area, and therefore proportional to the distance of the target from the center of the field of view. Proportional control is the most rapid and efficient type of control, minimizing the tendency of a missile to overshoot or to hunt about the course to its target. A proportional control system is substantially necessary for the control of jet or rocket propelled missiles where an extremely fast control system must be used.

A further advantage of the present invention is an automatic volume control of an amplifier in the circuit of the seeker. It selects only the signal frequency from the hottest bolometer in the bolometer bank or image area. Since a hot target radiates much more heat energy than its background, where heat radiations of different intensities are applied to two bolometers, signal from the hotter bolometer dominates and the seeker follows the target in the field of view since that target radiates the more effective heat energy.

Another advantage of the improved seeker that is described herein as compared with the usual scanning type of seeker is that energy is stored on a bolometer receiver as long as the position of the target does not change with respect to the seeker axis. For example, in a scanning device covering 100 image receivers per sec., energy only falls upon each receiver bolometer for 1/100 of a second. In the improved seeker, energy would be absorbed on a given receiver bolometer as long as the target did not move appreciably relative to the seeker axis. If the target image remained on one receiving bolometer for 0.5 second the amount of energy absorbed by the receiver would be 50 times the energy absorbed by the receiver of 0.01 second scanning time per bolometer. This extra sensitivity would be of special advantage at long ranges, when the received signal is very weak and the target would stay in approximately the same position relative to the seeker axis for a considerable fraction of a second.

A further advantage is that microphonic effects can be reduced to a minimum in the new seeker, since it contains no vibrating, rotating or oscillating mechanical parts such as mirrors, or optical heads.

Referring now to the accompanying drawings:

Fig. 1 is a block diagram of the electrical circuit for the present seeker;

Fig. 2 is a functional diagram of the seeker, said diagram being partly in block form and partly schematic, showing wave diagrams, shapes of the currents as they flow through particular pieces of apparatus making up the assembly shown in Fig. 2. Arrows indicate which diagram corresponds to the current generated in a particular piece of apparatus;

Fig. 3 is a combination block and schematic circuit diagram (or of a modified circuit) further illustrating the combination of apparatus required to bring about the circuit functions. It corresponds in general to Fig. 2, but different parts of that circuit are illustrated in greater detail in Fig. 3 than in Fig. 2;

Fig. 4 is a front elevation of a circular bank of bolometers hereinafter called the bolometer-receiver;

Fig. 5 is a diagrammatic side elevation of a section of the bolometer-receiver and its associated optical system and electrical connection;

Fig. 6 is an enlarged sectional view of a bolometer and its shielding assembly and a schematic diagram of its associated bridge circuit;

Fig. 7 is a longitudinal section of a special variable resistor employed in the circuit;

Fig. 8 is a schematic diagram of that part of the circuit beyond the bolometer bridge outputs and shows connections enabling the use of a common automatic volume control to the separate bolometer circuits and the elimination of a mixer for said circuits. Associated wave diagrams connected by arrows to the main diagram show the wave shapes at various points of the circuit;

Fig. 9 is an alternative circuit to Fig. 8 which does not however eliminate the automatic volume control. Associated wave diagrams are used as in Fig. 8.

Referring again to Fig. 4, **10** is a bolometer-receiver consisting of four quadrants **10***a*, **10***b*, **10***c*, and **10***d* which are arranged in clockwise order. The receiver could be divided into more divisions if it were so desired so long as they were symmetrically disposed. Each quadrant is divided into four bolometers **11***a*, **11***b*, **11***c*, and **11***d*, respectively, from periphery to center.

As will be seen from Fig. 6, the bolometers, for example, **11***a*, is mounted adjacent to a metal block **12** which bears another bolometer **13** on the other side thereof. The reason for such construction is that the shielded bolometer **13** is provided merely for reference. That is to say, the unshielded ones **11***a*, **11***b*, etc., are the only ones to be heated directly by the received signal. Therefore, a temporary heat differential is established between bolometer **11***a* and bolometer **13** long enough for the signal to actuate the circuits. After this is accomplished, the signal's heat flows into the block **12** and ultimately becomes distributed between the exposed bolometers **11***a*, etc., the block **12** and the shielded bolometers **13**, so that no heat difference remains to cause any electrical consequence.

The bolometers are not, however, mounted directly on the block **12**. A space **14** remains under the central areas of the bolometers and then upper and lower edges are gripped in mountings **15** of low electrical resistance. The bolometers themselves are thin deposits of metal mounted on a thin insulating film, for example of synthetic resin varnish.

The following method may be used to prepare the bolometers: A plastic plate may be molded with an opening the approximate size of the bolometer elements. The mounts **15** can be the edges of such a plate. After immersing such a plate in water, a thin plastic film can be formed on the surface of the water by pouring synthetic resin varnish thereon to the desired thickness. The plate can then be lifted out of water the film covering the opening. After the film dries, a mica stencil (not shown) is cut with openings the approximate size of the film and metal vapor is allowed to evaporate in vacuo and to deposit on the plastic film, thus forming the bolometer. Heavier metal deposits are then made at the edges of which fine wires **16** are attached by means of Wood's metal. Cellulose acetate or nitrate with a very small amount of "Glyptal" lacquer has been found satisfactory for making the plastic film.

Referring now to Figs. 2 and 3, a master oscillator **17** is provided to control a multi-vibrator **18**, the latter being adapted to furnish sixteen harmonics of the fundamental frequency. Sixteen frequencies are necessary because there are sixteen bolometer elements and each such element must be provided with its own frequency channel. The harmonic frequencies are kept in the radio or supersonic range so that the size and weight of filter circuit parts is held to a minimum. The harmonics are picked off the vibrator **18** by sixteen filters **19**, of which only two of the extreme limits of the scale are shown. The 16 filters feed, therefore, as will be shown, each bolometer and the ones shown feed the bolometers designated **11***a* and **11***p*. The upper represented circuit is for the former and the lower one for the latter.

The currents from filters **19** are fed to an amplifier network **20** in which it is amplified, and thence to transformers **21**. The latter convert the amplified radio frequencies to low voltage, relatively large current outputs that are impressed across special, balanced bolometer bridge circuits **22**. In the top bridge circuit, **11** indicates any bolometer strip of which **11***a* is taken as an example and **13** is a bolometer made in an exactly identical manner but placed behind the shielding block **12** so that it is shielded from radiation in the field of view. The resistors **23** and **26** are of the ceramic fixed type. **24** is a variable resistor for balancing the bridge. To reduce inductance and capacity to a minimum, resistor **24**, shown in section in Fig. 7, consists of a thin metallic deposit on the inside of the outer cylinder **32**, variable pickoff being obtained by the spring fingers **33** of an inner concentric metal cylinder **31** slidable therein. **25** is a resistor with the same dimensions and pickoff point as resistor **24** but with a thick instead of a thin metallic film. Its function is to balance that arm of the bridge in which it is inserted.

Resistors **24** and **25** are duplicates except that, as stated, **25** has a thick layer of platinum on the inner side of cylinder **32** whereas **24** has a thin one. By this means, when the resistance is varied by sliding the inner tube **31** longitudinally, the pickoff fingers **33** are moved together so that there will be the same change in the capacity or inductance, but a difference in the resistance. The tubes **31** of both resistors may be made to be slidable by a single motion.

It is necessary to reduce all inductance and capacitance to very small values, to make connections as short as possible and symmetrical, with sufficient rigidity to limit vibration. Each bridge is balanced for its associated frequency by means of a sensitive detector (not shown). When radiation falls upon a bolometer such as **11**, the balance is upset and a voltage is impressed across pickoff resistors **27** which are connected in series.

Resistances **27** are connected to the bridge circuits **22** by leads **28** and **29**. All of them end at the resistances **27**. The ends of the series of resistors **27** are connected to an amplifier **30** which is provided with an automatic volume control **34** (see Fig. 2) of the conventional type and is designed to act also as a limiter. The voltage impressed across amplifier **30** is equal to the sum of the voltage across the separate resistors **27**. It is to be noted that the voltage across one resistor **27** is not shunted by the other resistor **27** since each bridge is isolated by a transformer **21**.

One function of resistors **27** is, therefore, to act together as a mixer for the output of the sixteen bridge circuits. Amplifier **30** receives a signal from the output of said mixer, but the automatic volume control **34** supplies sufficient bias so that only the positive peaks of the strongest signal come through the first section of the amplifier. These peaks or "pips" have the same frequency as one of the bolometers, but are no longer sine waves. They have many Fourier harmonic components that would pass through a bolometer quadrant filter bank **40** wherein are disposed the different output filters **35**, **36**, **37**, **38**, and also those of a second series **61**, **62**, **63**, and **64** in a frequency-selective stepped resistor bank **41** (Fig. 3). **62***a*, **63***a* and **64***a* are each four channel filters connected respectively to the outputs of filters **35**, **36**, **37** and **38**. Filters **62***a*, **63***a* and **64***a* are each identical with **61**, **62**, **63** and **64**, collectively. They would tend to actuate a number of control circuits instead of only one. To restore a sinusoidal wave shape, the pips are now impressed on the control grid of a pentode tube **43**, the plate of which is connected in series with anti-resonant tank circuits **44**, **45**, **46**, **47** corresponding to the given bolometer frequencies. Only the tank circuit with the resonant frequency of the pips is excited, and gives a sine wave output which will pass through the proper output filter.

The Fourier harmonics of the pip excite some of the anti-resonant circuits of the sine wave generator **39**, but the sine waves so generated are smaller in amplitude than the sine wave produced by the fundamental of the pip, and are readily suppressed by limiter **48** in Fig. 2.

Stepped attenuator filter circuit **41** comprises attenuators **65** to **68**, inclusive, in series, respectively, with pick-off resistors **42a** to **42d**, inclusive, one pair such as **65** and **42a**, for example, give a signal four times as great as the signal from **68** and **42d**, since resistors **65**, **66**, **67** and **68** are to each other as the integers 1, 2, 3 and 4. It is the function of the limiter **48** (see Fig. 2) to reduce all signals to the same voltage amplitude. This must be done without changing the wave shape, for if, for example, the top of a wave were cut off, many new Fourier component frequencies would be produced that would pass through the wrong output filters. Therefore, since a multivibrator was used for the input frequencies, they are to each other as the integers chosen. Then if the top of the sine waves were to be cut off so that it approached the characteristics of a square wave, some of the chosen 16 harmonics would be present in appreciable size, and each harmonic would be routed through a different output filter. It is necessary therefore to reduce not only the amplitudes of the various signal frequencies to the same amplitude, but to carefully preserve the sinusoidal wave shape.

In the limiter **48**, the given signal is impressed on the grid of a tube **49**, the plate thereof being in series with a resistance **50**, a battery **51**, and a tube **55** which is used as a variable resistance. The output signal is taken from across the tube **55** and will be nearly proportional to the resistance of that tube if a large value of resistance **50** is used. The voltage drop across tube **55** is also impressed upon a resistor **52**, a rectifier **53**, and a battery **54**. The grid pickoff for tube **55** is derived from resistor **52**. No current will flow through resistor **52** until the voltage drop across tube **55** is greater than the voltage of battery **54**. When this occurs, a relatively large voltage will be impressed across the grid of tube **55** and its resistance will drop rapidly until its IR drop just exceeds voltage from the battery **54**.

Since the resistance of tube **55** is only a small part of the total resistance in the plate circuit of the tube **49**, there will not be any appreciable change in the limiter output wave shape from the signal impressed on the grid of tube **49**. A condenser **56** is connected to resistance **52** by a sliding contact that may be adjusted so that condenser **56** is charged rapidly when rectifier **53** passes current, but requires a number of cycles to discharge through the larger portion of resistor **52**. This action maintains the voltage across the grid of tube **55** with only a gradual drop-off between positive peaks, and prevents appreciable distortion of the wave shape. Preservation of the wave shape is aided by the fact that all frequencies reaching the limiter have been made nearly the same size by the automatic volume control and sine wave generator, the value of tank circuits **44**, **45**, **46** and **47** having been adjusted for this result.

The output of the limiter **48** is divided by band filters **35**, **36**, **37** and **38**, so that the signal frequencies from the bolometers of one quadrant are routed via one of these filters to that quadrant control. If the strongest signal is in the first quadrant, the signal will go through rectifier **69** (see Fig. 1) to the first quadrant control **90**. The size of the output signal will depend upon the bolometer strip from which it originated, being proportional to the distance of the bolometer strip from the center of the image area. The simple tuned circuits that separate the signals from the bolometer strips of a given quadrant are designed to have attenuation inversely proportional to the distance of the bolometer from the center. Thus if the signal from the bolometer **11a** were the strongest, it would be the only one to reach the band filters, and would pass through composite filters **35** and one filter **61**. The amplitude of the signals reaching the filters **35** to **38**, inclusive, is the same because of the action of the limiter **48**, regardless of the size of the signal or the bolometer strip from which it originated. But the top filter **61** has such attenuation that a signal passed through the top filter **61** produces about four times the signal that it would have if it came through the bottom filter **64**. The signal from bolometer **11a** is picked off from one of four stepped attenuators or pick-off resistors **42a**, **42b**, **42c** and **42d** in series and is impressed on rectifier **69**, the output of which gives a voltage proportional to the angular displacement of the target from the center of the image field. The quadrant control **90**, which is a servomotor is therefore driven at a speed directly proportional to the voltage of the rectifier output until it aligns the horizontal axis of the missile with the source of the controlling heat signal. When that has occurred, the heat signal strikes the exact center of the bolometer bank where there are no sensitive surfaces. Therefore the servomotor stops for lack of signal-induced current until the missile wanders off its course sufficiently to start a new correction cycle.

Superposition of different waves in the mixing circuit (such as pickoff resistors **27**) of Fig. 3 may lead for certain frequencies to serious intermodulation so that the pips of Fig. 2*d* would be irregular in height, and some might be depressed, giving an irregular pip frequency. It may be necessary on account of such conditions to eliminate the mixing elements **27** and to apply an automatic volume control **70** in common to the separate bolometer output circuits as indicated in Figs. 8 or 9. Thus in Fig. 8 one lead **29** from each of the sixteen bolometer bridge circuits, is connected in common to the cathode biasing circuit **70**, the other lead **28** being connected to the grids of the tubes **74**. The pickoff resistors **72** are large relative to the plate resistors **73**, so that the output from one pickoff resistor **72** is not shorted too much by the other resistors **72** in parallel through the plate resistors **73** to ground. The one pip frequency that comes through the depressing bias common to the tubes **74** is impressed upon the grid of a tube **30**, the output of which feeds into the sine wave generator **43** to **47**, inclusive, of Fig. 3.

Or, as in Fig. 9, each bolometer bridge output circuit is impressed across the grid of a tube **80** of which only two are shown with their circuits. The outputs of rectifiers **81** and **81'** charge a condenser **82** to a value proportional to the largest bolometer output from the plates of tubes such as **80**. The voltage of condenser **82** is impressed on resistor **83**, thereby furnishing a common bias and automatic volume control for all the tubes **80** with a time constant determined by the values of condenser **82** and resistor **83**. If the largest signal is received from bolometer **11a** only, the peaks of these signals will cause electron pulses to pass to the plate of the tube **80** and hence to a coil **84** in series with battery **86** and resistor **88**. This coil **84** is coupled to the antiresonant pickoff circuit **85**, which is tuned to the fundamental Fourier component of the signals impressed on tube **80**. The pickoff circuit **85** is excited and impresses a voltage across the limiter **48** of Fig. 2. Since the pickoff circuits **85** are similar to other circuits for other frequencies, only one being excited at any one time, the unexcited ones having a relatively low impedance, a single sinusoidal wave is produced of the frequency of the bolometer with the largest signal output.

In use, the bolometer bank is mounted as shown in Fig. 5 at the focal spot of a fixed parabolic mirror **91**, the bolometer **13** facing the mirror surface. The mirror **91** with the bolometer bank is mounted in the nose (not shown) of the missile to be guided. The nose is made preferably of a single piece of material transparent to heat rays such as silver chloride, without ribs so that there is no additional resistance to the heat signal than occurs in its passage through a sheet of uniform thickness. The mounting stem **92** may be hollow so that it can be utilized as a conduit to bring electric wires **16** to the bolometer bank. Before launching the missile, which may occur from ground by means of a ramp or catapult or from an airplane in flight, the current sources are turned on, the openings in the bolometer chamber closed to keep out drafts and the launching may then take place in the conventional manner.

Since a missile is customarily provided with explosives and a detonating mechanism therefor, it is to be understood that all such conventional additions may be made to the missile to promote effective destruction of enemy units or installations.

Numerous modifications such as the substitution of equivalents will suggest themselves to those skilled in the art and such modifications may be made without departing from the spirit of the invention.

The invention claimed is:

1. In a heat seeker, the combination which comprises a bank of bolometers disposed to receive heat signals and to represent an optical field of view in quadrants thereof, a Wheatstone bridge circuit for each bolometer, said circuit including said bolometer in one of its arms, means for supplying oscillatory current to said bridge circuits, an outlet channel for each circuit, said outlet channel governing an external control and a system of primary and secondary filters to route the signal from a given bolometer to the proper output channel to direct a control first by the primary filters to identify the originating quadrant, then by secondary filters to identify that portion of the originating quadrant which has received the signal.

2. In a heat seeker, the combination which comprises a bank of bolometers disposed to receive heat signals, a Wheatstone bridge circuit for each bolometer, said circuit including said bolometer in one of its arms, means for supplying oscillatory current to each of said circuits, a mixer for the output of all of said circuits, an amplifier for said combined signals, an automatic volume control for said amplifier whereby to produce such a bias that only the peaks of the strongest signals are transmitted, an electronic tube having a grid connected to receive said peaks, and also a plate, a system of tanks circuits connected to the plate of said tube whereby a sinusoidal wave tuned to the same frequency as that of the signal input peaks fed to the amplifier is created by said tank circuits and a system of filters connected to said tank circuits for routing the sinusoidal waves to output channels indicated by the frequency of the filters connected thereto.

3. In a heat seeker mounted upon a missile, a bank of heat sensitive elements disposed as a bank to receive heat signals, an electrical circuit capable of unbalance, said circuit including one of said heat sensitive elements exposed in a position where it can cause electrical unbalance when it receives a heat signal, means for electrically powering said circuits with oscillatory current, means for creating a different current frequency in each circuit, a second bank of identical heat sensitive elements which is shielded from heat radiation, each individual element thereof being included in some one of said circuits capable of unbalance, with one of said exposed heat sensitive elements whereby the shielded element will serve as an electrical standard of reference, an amplifier connected to the output sides of said circuits, a system of filters connected to said amplifier to route the signals to the proper channels for proportional control and stepped attenuators connected to the outputs of said filters, said attenuators having impedance values which differ from each other so as to give signal outputs which are proportional to the angular displacement of the target with respect to the center of the bank of exposed heat-sensitive elements.

4. In a heat seeker mounted upon a missile, the combination which comprises a bank of bolometers exposed to heat signals, an identical bank of bolometers shielded from radiation, a heat absorbing block between said banks, an electric circuit including a Wheatstone bridge for each bolometer pair including a shielded and an exposed bolometer, one arm of said bridge including a shielded bolometer and its companion arm including an exposed bolometer, the other two arms of said bridge including respectively fixed resistors with negligible capacitance and inductance and a variable resistor having negligible inductance and capacity in the one arm and a similar variable resistor in the other arm so that inductance and capacity may be the same in both of the latter arms, an amplifier connected to the output of said bridge circuits and a filter system connected to the output of said amplifier and to the missile controls to route signals through appropriate channels to give proportional control to the missile.

5. An automatic control circuit for mounting on a missile said circuit, comprising in combination, the elements connected together in the order named, a master oscillator, a multi-vibrator, filters for separating the output of the multi-vibrator into at least sixteen different harmonic channel circuits, an amplifier for each circuit, a transformer for each circuit, a Wheatstone bridge for each circuit, said bridge having in its four arms respectively, a bolometer exposed to heat signals as a member of a disc-like bank, a bolometer shielded from heat signals, fixed and variable resistance in which the inductance and capacity are negligible, fixed and variable resistance substantially devoid of inductance and capacity exactly balancing the just mentioned fixed and variable resistance, a mixer for the bridge outputs, an amplifier for said mixer output, an automatic volume control for said amplifier output whereby to transmit only the peaks of the strongest signals, a sine wave generator to receive said peaks and to incorporate them into a sine wave, a limiter to bring the sine wave to constant voltage amplitude, four filters for the output of said sine wave generator to route the signals current therefrom according to the quadrant of the disc of bolometers from which their location and frequency originates, four tuned filters for each one of said quadrant-locating filters, attenuators in series with each filter, said attenuators together constituting a series having the relation and value of integers in respect to each other, a rectifier for the output of said attenuators, said rectifier being connected to one control of said missile whereby said control will be actuable proportionally in at least four steps according to the impedance value of the attenuators through which the actuating current is transmitted.

6. In an automatic control circuit according to claim 5, the modification which comprises a triode electronic tube for each bridge output circuit, said circuit being connected to the grid of said tube, an automatic volume control furnishing a common bias for each of said tubes whereby only the peaks of the signals received from the bridge circuit will pass to the plate of said tube, an anti-resonant pickoff circuit tuned to the fundamental Fourier component of the peaks transmitted to the plate of said tube, a limiter connected to the output of said pickoff circuit, and a limiter to bring the sine wave generated by the tube to constant voltage and amplitude.

7. In a heat seeker, a proportional control system comprising a plurality of bolometer-receivers an amplifier, an automatic volume control therefor arranged to produce such a bias that only the peaks of the strongest signals from the bolometer-receivers will come through, electronic elements including a vacuum tube of at least three electrodes including a grid and a plate, the grid being adapted to receive said peaks, a system of tank circuits connected to the plate of said tube so that a sinusoidal wave may be picked off that tank circuit which is tuned to the same frequency as the signal input peaks.

8. In a heat seeker, a proportional control system comprising in combination a group of bolometer-receivers in which the units are characterized by individual impressed frequencies, an amplifier, an automatic volume control on said amplifier, said control being arranged to pass only the peaks of the largest signals, a plurality of tank circuits arranged to generate a sinusoidal wave tuned to the frequency of the incoming signal affecting one

bolometer-receiver and filter circuits arranged to route said sinusoidal wave to the proper mechanical control element and to exert proportional control thereon.

9. In a heat seeker, a proportional control according to claim 8 having in addition an attenuator in each of the filter outputs, said attenuators being so arranged as to give signals proportional to the angular displacement of the target with respect to the axis of the seeker.

10. In a heat seeker, a proportional control system comprising a receiver system in which different units are characterized by different frequencies of impressed voltage, a bridge in which a receiver unit exposed to radiation forms one arm of the bridge and a substantially identical unit shielded from radiation forms the other symmetrical arms, the remaining arms comprising fixed resistors having negligible capacitance and inductance in series, in one arm, with a double telescopic cylindrical resistor formed by a thin film metal deposit upon one cylinder and an outer metallic cylinder with spring fingers to slide over it and a similar cylindrical resistor in the remaining arm of the bridge, the outer cylinder having the same position but there being a thicker metallic deposit on the inner cylinder so that the inductance and capacitance may be the same in both arms, an amplifier, and a filter system arranged to route the signals from the bridge through the proper channels for proportional control.

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