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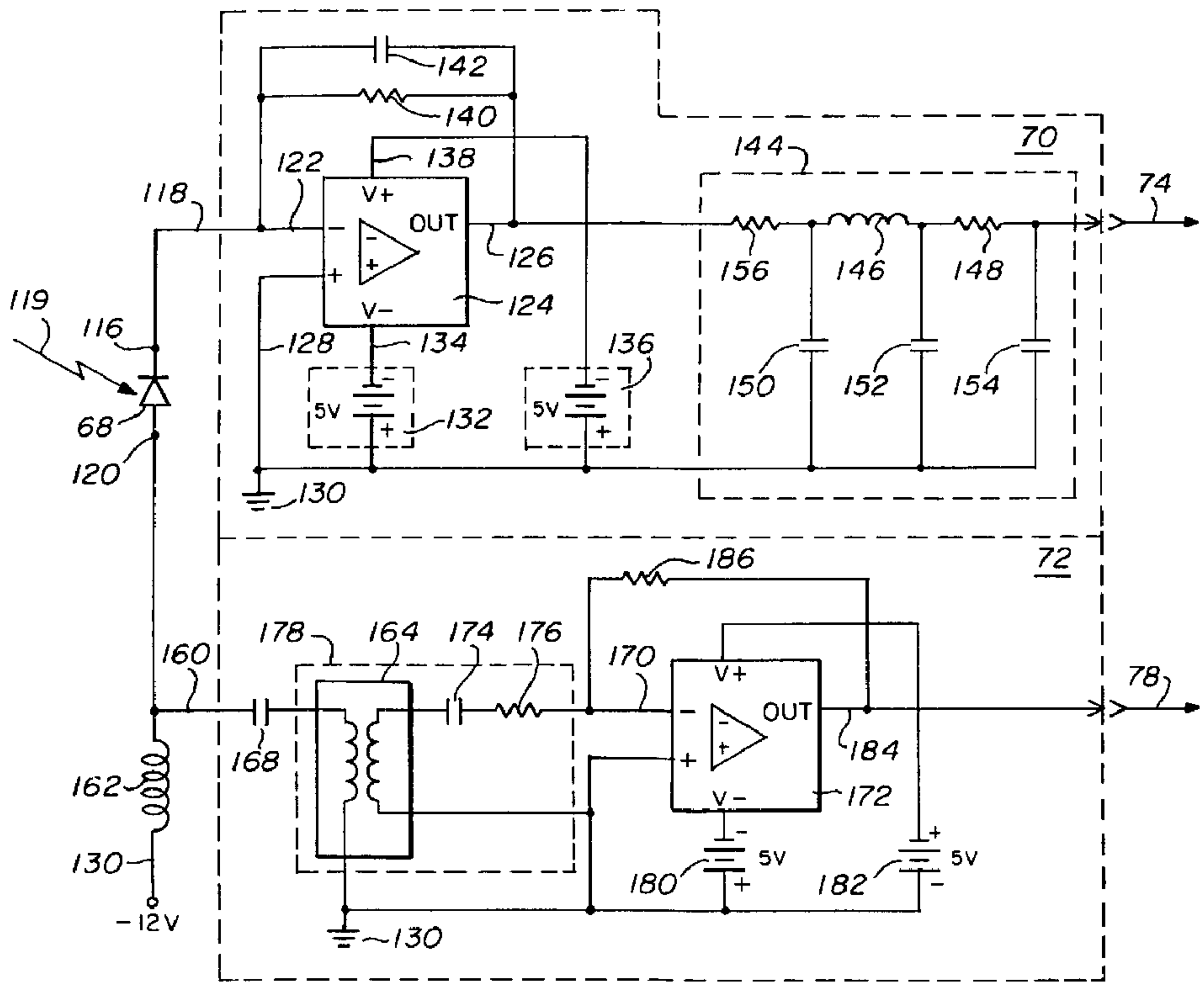
(54) Titre : DISPOSITIF ET TECHNIQUES PERMETTANT D'EXTRAIRE DEUX BANDES DE FREQUENCE DISTINCTES DE LA LUMIERE RECUE PAR UNE PHOTODIODE
(54) Title: APPARATUS AND METHODS FOR EXTRACTING TWO DISTINCT FREQUENCY BANDS FROM LIGHT RECEIVED BY A PHOTODIODE



(57) **Abrégé/Abstract:**
Methods and apparatus for extracting two distinct frequency bands from light received by a photodiode. Signals of a first frequency band such as, for example, less than about 3 MHz are recovered by circuitry connected to the cathode of the photodiode, and signals having a different frequency band such as, for example, between about 3 MHz to 50 MHz are recovered by circuitry connected to the anode of the photodiode.

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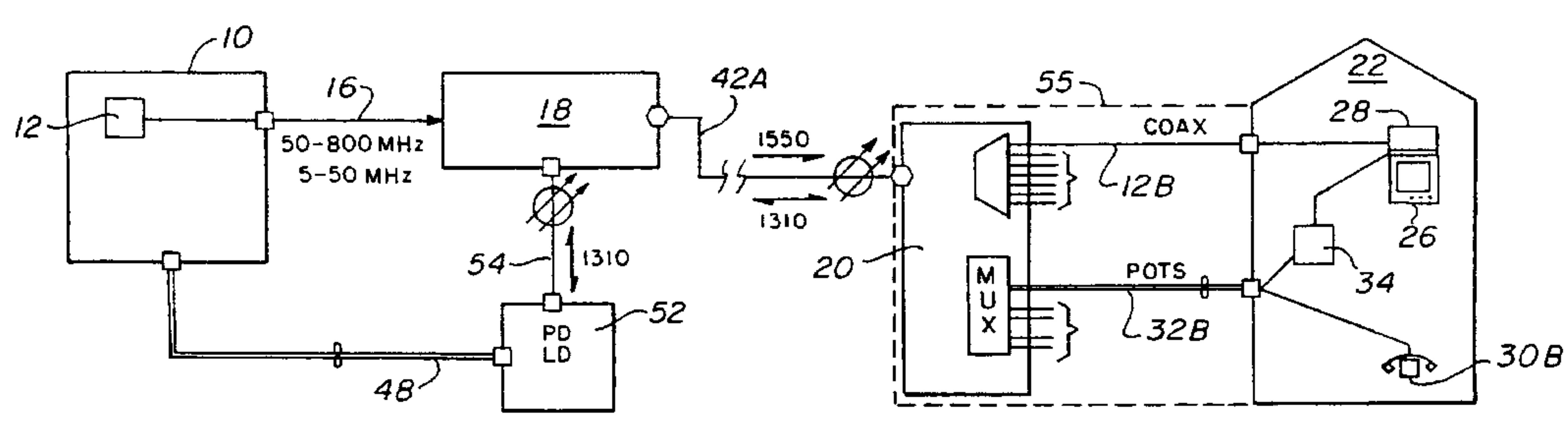
(54) Title: APPARATUS AND METHODS FOR EXTRACTING TWO DISTINCT FREQUENCY BANDS FROM LIGHT RECEIVED BY A PHOTODIODE



(57) Abstract: Methods and apparatus for extracting two distinct frequency bands from light received by a photodiode. Signals of a first frequency band such as, for example, less than about 3 MHz are recovered by circuitry connected to the cathode of the photodiode, and signals having a different frequency band such as, for example, between about 3 MHz to 50 MHz are recovered by circuitry connected to the anode of the photodiode.

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APPARATUS AND METHODS FOR EXTRACTING TWO DISTINCT FREQUENCY BANDS FROM LIGHT RECEIVED BY A PHOTODIODE

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to methods and apparatus for carrying on simultaneous communications over optical fibers, and more specifically to methods and apparatus for extracting two different frequency bands from light centered about a single wavelength. In a preferred embodiment the single wavelength of light provides both bidirectional TDM (time division multiplexing) telephony communication and TV control signals which are returned by the telephony communication path from the customers to the TV source by multiplexing the control signals with the telephony signals.

2. DESCRIPTION OF RELATED ART INCLUDING INFORMATION DISCLOSED UNDER 37 CFR 1.97 AND 1.98

The communications industry is using more and more optical or light fibers in lieu of copper wire. Optical fibers have an extremely high bandwidth thereby allowing the transmission of significantly more information than can be carried by a copper wire transmission line such as twisted pairs or coaxial cable.

Of course, modern telephone systems require bidirectional communications where each station or user on a communication channel can both transmit and receive. This is true, of course, whether using electrical wiring or optical fibers as the transmission medium. Early telephone communication systems solved this need by using a hybrid interface which allows transmission and reception on the same copper pair loop, and this approach is still used in part of the transmission path. It is especially used as the signals get closer to the end users. Although twisted pairs and coaxial cables are used in homes and distribution terminals close to the home end user, some modern telecommunication systems now use micro-wave and optic fibers as transmission mediums. In addition TCM (time compression multiplexing) is often used in optical transmission so that a signal optical fiber can carry communications in both direction. DDM (direction division multiplexing) may also be used to carry bidirectional signals on the same fiber as long as signal reflections do not corrupt the transmission.

However, because of extremely high bandwidths available for use by an optical fiber, a single fiber is quite capable of carrying a great number of communications in both directions. One technique of optical transmission is WDM (wavelength divisional multiplexing) and uses different wavelengths for each direction of travel.

Yet another and simpler technique for using a single optical fiber for telephone systems is TCM (time compression multiplexing) and is sometimes referred to as a "ping-pong" system. The system operates by using light operating at a single center wavelength, and uses a single optical fiber and often even a single diode, for both converting electrical signals to optical signals and converting received optical signals to electrical signals. TCM systems have the obvious advantage of requiring fewer components.

However, as mentioned above, optical fibers have extremely high bandwidths and use of an optical fiber for a single TCM or DDM telephone channel is a very ineffective use of the fiber and, in fact, the available bandwidth of an optical fiber makes it possible to use a transmission technique such as TCM or DDM at one frequency and then by the use of WDM technology to use another technique at a second frequency.

Another area of rapidly growing technology is providing TV signals by cable from a station or source to a multiplicity of subscribers or users. In the past, such signals were and still are typically transmitted by the use of coaxial cables (e.g. cable TV). However, the use of optical fibers for transmission allows broad band transmission to a large numbers of customers and substantially all of the transmission of TV signals is one way (i.e. unidirectional). However, even though upstream transmission is extremely small compared to the transmission of TV signals downstream, there is still a need to provide such return signals, which are typically control or information signals.

It is also advantageous to provide return control signals to the TV signal source or station with respect to each customer or subscriber by a telephony transmission so that it is not necessary to dedicate a frequency or wavelength of light full time to seldom used RF Return transmitted signals.

Unfortunately, extraction and subsequent effective separation of a distinct high-level frequency band on the order of 5-50 MHz for RF return signals and a distinct low-level frequency band of less than 3 MHz for telephony signals has required bulky and expensive transformers and/or filtering circuits.

Therefore, it would be advantageous to provide simple and inexpensive apparatus for extracting two different signals from a single wave length of light where one of the signals operates at a relatively high frequency band and the other operates at a relatively low frequency band.

SUMMARY OF THE INVENTION

The above objects and advantages are achieved in the present invention by methods and apparatus which recover or extract two distinct frequency bands from light having a selected center wavelength by using a single photodiode having two different recovery circuits which are electrically isolated from each other. One of the two circuits is connect to the cathode of the photodiode and the other circuit is connected to the anode of the photodiode. In one preferred embodiment, the photodiode, which is located between the two recovery circuits, is the only electrical connection between the circuits except for a common "ground" or "voltage source". Therefore, there is a very high impedance separating the two circuits, yet the current flow at the anode and cathode are almost exactly the same. In one embodiment, signals having a relatively low frequency of less than 3 MHz, such as POTS or telephone signals, are recovered by the circuitry connected to the cathode. Thus, these signals can be amplified without concern for drift, etc. In a similar manner, signals relatively high and having a frequency of between 3 MHz and 50 MHz are recovered by the circuitry connected to the anode of the photodiode. These signals can also be amplified without concern for drift, etc.

Although the present invention is particularly useful for extracting one set of signals having a frequency of less than 3 MHz and a second set of signals having a frequency greater than 3 MHZ (e.g. 3 MHz to 50 MHz), it should be understood that the invention can be used to extract first and second signals at substantially any two frequency ranges so long as the frequency ranges are distinct from each other.

Accordingly, in one aspect of the present invention there is provided a method of extracting two frequency bands from a photodiode receiving light of a selected wavelength comprising the steps of:

exposing a photodiode to light carrying signals at first and second frequency bands and having a selected wavelength;

amplifying a first output generated at a cathode of the photodiode in response to the light;

filtering the first output to recover signals at the first frequency band;

filtering a second output generated at an anode of the photodiode in response to the light to recover signals at the second frequency band;

amplifying the signals at the second frequency band; and maintaining isolation of circuitry between the anode and the cathode of the photodiode.

According to another aspect of the present invention there is provided a method of extracting signals having first and second frequency bands from a photodiode exposed to light having selected wavelengths of light and carrying said first and second frequency bands comprising the steps of:

modulating said selected wavelength of light with a first signal having a first frequency band and with a second signal having a second frequency band, said first frequency band comprising frequencies which are less than said second frequency band;

exposing a photodiode to said selected modulated wavelength of light;

detecting signals at one of said first and second frequency bands at the cathode of said photodiode by first amplifying and then filtering an output at said cathode; and

detecting the other one of said first and second frequency bands at the anode of said photodiode by first filtering and then amplifying and output at said anode.

According to yet another aspect of the present invention there is provided apparatus for extracting signals at first and second bandwidths from a photodiode exposed to selected wavelengths of light comprising:

a photodiode having a cathode and an anode, said photodiode generating a current therethrough in response to light having substantially said selected wavelength;

a first detection circuit connected to said cathode for monitoring said current generated by said photodiode and for detecting signals within a first frequency band, said first detection circuit including an amplifier operable to amplify a first output generated at said cathode of said photodiode in response to said light, said first detection circuit operable to filter said first output to recover signals at said first frequency band; and

a second detection circuit connected to said anode for monitoring said current generated by said photodiode and for detecting signals within a second frequency band different than said first frequency band, said second detection circuit including a filter operable to filter a second output generated at said anode of said photodiode in response to said light to recover signals at said second frequency band, said second detection circuit including an amplifier operable to amplify said signals at said second frequency band, said first and second detection circuits substantially isolated from each other except through said diode.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the present invention will be more fully disclosed when taken in conjunction with the following Detailed Description of the Invention in which like numerals represent like elements and in which:

FIG. 1 is a prior art block diagram showing the present transmission and distribution of a typical coaxial TV and POTS telephone system;

FIG. 2 shows a POTS telephone system and a fiber optic TV distribution system having 1550 nanometer light carrying TV signals in one direction and 1310 nanometers of light carrying telephony signals in both directions;

FIG. 3 shows a block diagram of a communication system incorporating the present invention wherein portions of an existing POTS telephone system and a coaxial TV signal distribution system are used with a single optical fiber for carrying the TV signals at 1550 nanometers of light downstream and the telephony signals in both directions at 1310 nanometers;

FIG. 4A and 4B show detailed block diagram of the system of FIG. 3;

FIG. 5 is a block diagram illustrating the basic concepts of the present invention; and

FIG. 6 is a circuit diagram showing the unique circuitry of a preferred embodiment of the present invention recovering two frequency bands from a light wave carrier.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, there is shown a typical prior art transmission and distribution system for cable TV and normal telephone service, referred to as POTS (plain old telephone service). As shown, cable TV source location 10 has cable TV transmission equipment 12 which may originate from several sources including a satellite receiver 14. The TV equipment 12 would then amplify this signal and send it out typically on a coaxial line such as line 16 to a distribution system which may include several stations such as station 18 where the signal is again amplified and further distributed to an even larger multiplicity of locations. Such re-amplification and further distribution may occur several times but eventually will arrive at a local distribution terminal 20 by means of a coaxial cable 12A from which it is then distributed to a home or building 22 by a coaxial cable 12B. As shown distribution terminal 20 may also provide TV signals to other buildings or homes such as indicated by bracket 24. Once the TV signal is received at building 22, it will then typically be provided to a TV set 26 directly or to a set-top or cable TV box 28. If the signal is first provided to the set-top box 28, it is then directly provided to TV set 26. It should be appreciated that the direction of travel for such signals is unidirectional downstream. That is, it travels from the cable TV signal source 10 to the set-top box 28 in the building or home 22 at frequencies of between about 50-860 MHz. If information is to be carried upstream or back to source 10, it will typically be at between 5 -50 MHz.

Also shown is a typical telephone system or POTS which of course is two-way communication typically carried by means of a twisted pair of wires. In the example shown in FIG. 1, if someone at the cable TV signal source location 10 wishes to talk with someone at building 22, the telephone 30A is used in its normal manner. The two-way conversation is carried on between the person in building 10 using telephone 30A and by a person using telephone 30B in the home or building 22. This communication is typically carried through a pair of twisted wires such as indicated by 32, 32A, and 32B. In recent years, the regular telephone distribution system has also been used to provide communications between computers. This is done by the use of a modem 34 which connects a computer to the telephone line. As was the case with the TV signal distribution, there are typically several stations or substations between the two telephones 30A and 30B located at the building 10 and the building 22, respectively. Such distribution terminals or stations allow telephone services between all subscribers with which we are all well aware. However, as shown at distribution terminal 20A, there may also be several other buildings or homes connected to distribution terminal 20A as indicated by bracket 24A. As was discussed earlier, communications between buildings 10 and 22 were typically accomplished through regular telephone service by individuals talking to each other. However with more efficient automation, telephone lines may also be connected up to the set-top box 28 as indicated by wires 36. In addition, in the distribution terminal 38 at the cable TV signal location, there is also a telephone connection to the TV signal equipment 12, such that it is now possible that requests to purchase movies or information concerning the TV signals and TV equipment can be communicated between the two locations.

As demands increase for more and more TV channels and better and more efficient transmission techniques without disruption and interference, the long runs of coaxial cable are simply becoming inefficient and inadequate. Thus as is shown in FIG. 2, there is an improved system for the transmission of TV signals between the TV signal source location 10 and the building or home 22. In the systems shown in FIG. 2, there is also shown a standard telephone or POTS system as discussed above.

In the improved television transmission system, however, the transmission is achieved by a fiber optical cable as indicated by fiber optical cables 42 and 42A. As shown in FIG. 2, the same coaxial cable 12B exist between the distribution terminal 20 and the home or building 22. However, also as shown distribution terminal 20 includes new equipment 46 which receives the transmitted light on optical fiber 42 and converts it to electrical signals and conversely receives electrical signals from 12B and converts the electrical signals to light signals for transmission on optical fiber 42. However as will be appreciated by those skilled in the art, the TV signals from the TV signal source building 10 travel continuously downstream. Thus, if bidirectional communications between the cable TV signal source 10 and the distribution terminal 20 are to take place, some sort of sharing of the individual optical fibers 42 and 42A as well as the copper wire 12B must be provided. Thus, in the example shown, the TV signals travel in a single direction (i.e., downstream) from the TV signal source at location 10 to the home or building 22 at least partway by light waves having a length centered around about 1550 nanometers. Any return communication traveling on optical fiber 42 is carried by a different wavelength of light such as 1310 nanometers which travels upstream to the TV signal source location 10. Likewise, if bidirectional communication is to take place on the single coaxial cable 12B between distribution terminal 20 and home or building 22, the transmission of such bidirectional communication transmission must also be at a frequency different from the TV signals. Thus, in the illustrated example, the 1550 nanometer light waves will be carrying electrical signals having a frequency band of between about 50 and 860 MHz which travel in a single direction from distribution terminal 20 to the home or building 22. The return signals from the set or set-top box at building 22 are then carried at about 5 to 50 MHz back to the distribution terminal 20 and then use modulated light having a wavelength of about 1310 nanometers to carry the signals. Thus, it is seen that it is possible by the use of a single optical fiber as well as using existing infrastructure copper wiring such as coaxial cable to transmit a broad frequency band of TV signals carrying multiple channels of TV information at one wavelength of light. The individual TV channels are then converted to electrical signals at a specific frequency within the 50-860 MHz frequency band. Conversely, electrical control signals within the 5-50 MHz frequency band are converted to light at a wavelength different from that provided in the downstream mode and transmitted back to the TV signal source location 10. The return wavelength of light in the illustrated example is 1310 nanometers. However, as was mentioned above using light at a separate wavelength of about 1310 solely for the return RF signals is not efficient use.

Referring now to FIG. 3 there is shown a simplified block diagram of a preferred embodiment of the present invention which takes partial advantage of the existing telephone and coaxial TV distribution systems while also using a single optical fiber path 42 and 42A for part of the transmission path between the TV signal source location 10 and the building or home 22. It should be noted that, although the following discussion is in terms of a single path for the coaxial or optical fiber cable between two locations 10 and 22, in actuality there may be a significant amount of multiplexing and de-multiplexing such that many, many subscribers or customers may be serviced by the single optical fiber and any other multiplexed cable. It should various locations in the distribution path. As shown, TV signal source location 10 provides signals from equipment 12 and, in this illustrated embodiment, the TV signals may be 50 to 860 MHz signals provided on copper wire, such as coaxial cable 16. Copper coaxial cable 16 carries the TV signals having a bandwidth of 50 to 860 MHz to a distribution terminal 18 which modulates light with the electrical TV signals. In one preferred embodiment, a particular selected wavelength is centered around about 1550 nanometers. Thus the light waves travel in a single direction from distribution terminal 18 to distribution terminal 20. Also as shown, electrical telephony signals may be carried by copper wires such as copper wires 48 which represent a twisted pair of normal telephone communication wires to a substation 52 where electrical telephony signals traveling in one direction are converted to light signals at a selected frequency and light signals at that same frequency traveling in the opposite direction are converted to electrical telephony signals. Thus, the fiber optic cable 54 shown between distribution terminals 18 and 52 carries telephony signals at a single wavelength of light typically selected to be about 1310 nanometers. The light signals at 1310 nanometers are able to travel in both directions on the single fiber optic cable 54 by the use of TCM (time compression multiplexing). Although TCM may not be suitable for higher density signals such as TV signals, it is quite adequate for lower frequencies suitable for transmitting the human voice as well as frequencies up to about 64 KHz, which is above human hearing. Time compression multiplexing simply stated means that time is broken up in substantially two portions or cycles such that signals travel in one direction during one portion and in the opposite direction during the other portion. Thus, distribution terminal 18 is connected to optical fiber 54 carrying the 1310 TCM (time compression multiplexed) modulated light and also receives 50 to 860 MHz TV signals from the TV signal source location 10. The 50 to 860 MHz electrical signals modulate light having a wavelength of 1550 nanometers. Thus, distribution terminal 18 also combines by WDM (wave division multiplexing) the 1310 nanometer light carrying telephony signals with the 1550 nanometer signal carrying the TV signals such that cable 42 carries 1550 nanometer signals in a downstream direction and carries 1310 nanometer telephony signals in both directions.

At distribution terminal 20, and as will be discussed in detail later, the electrical TV signals are extracted from the 1550 nanometer downstream traveling light. These electrical TV signals have a bandwidth of between 50 and 860 MHz. They are then distributed to various locations including home or building 22 as was discussed with respect to FIG. 1 and 2 above. In a similar manner, the TCM signals traveling downstream on 1310 nanometer light waves are routed to other equipment in distribution terminal 20 which extracts the electrical telephone signals from the 1310 nanometer light traveling upstream with other electrical telephony signals. The electrical telephony signals are then distributed from distribution box 20 by twisted wires 32B to the telephone 30B or other telephony equipment such as the computer modem 34 at home or building 22.

As was discussed with respect to the system of FIG. 2 above, it may be desirable to transmit certain types of television related control signals or "purchasing information" signals from the set-top box 28 or TV set 26 at building 22 back to the TV signal source location 10. As discussed earlier with respect to FIG. 2, such return information will have to be carried upstream at a different frequency band such as 5-50 MHz on the copper cable 12B and on a wavelength of light different than the 1550 nanometer light on fiber optic cable 42A. Thus, in addition to the telephone service which travels on a wavelength of light of 1310 nanometers, the 5-50 MHz electrical TV-related signals are also carried by the 1310 nanometer light. These electrical signals carrying the return RF or TV-related signals are multiplexed with the telephone service which travel on the 1310 nanometer light of the portion on the TCM cycle traveling from distribution terminal 20 to distribution terminal 18. At distribution terminal 18, the TV related control signals can be provided converted to electrical signals and then provided in a normal fashion to the TV equipment 12 or alternately distribution terminal 18 may split out the 5 to 50 MHz signals from the 1310 wavelength of light and provide the signal on coaxial cable 16 which is also carrying the downstream original television signals having frequency bands of 50 to 800 MHz. These 5-50 MHz signals traveling upstream go to the TV equipment 12.

Although in the embodiment shown in FIG. 3, the modulation of light waves and extraction of electrical signals for both telephone service and for TV signals is shown occurring at a remote distribution box 20, it will be appreciated that in the future it may be advantageous that a single optical fiber would be connected into a home or building 22 and the conversion from electrical signal to light signals and vice versa will take place in the building 22 itself as indicated by dotted line 55.

Thus, there has been discussed to this point generalized concepts for a new and improved telephony and TV signal distribution systems.

Referring now to FIG. 4A and 4B, there is provided a more detailed description of the system of FIG. 3 discussed above. As shown, the TV signal source location 10 provides output TV signals at 50 to 800 MHz from equipment 12 which travel downstream on copper wire 16. The electrical signals are then provided to laser diode 56 where the electrical signal at 50 to 860 MHz are then used to modulate light having a wavelength of 1550 nanometers. The 1550 nanometer light is then eventually provided to a wave division multiplexer 58 which is also connected to optical fiber 54 carrying light at a wavelength of 1310 nanometers and will be discussed later. Although it is possible that the output of the light emitting diode 56 could be provided directly to a wave division multiplexer 58, typically the light would go through a light amplifier such as EDFA (erbium doped fiber amplifier) 60. The amplified light signal from amplifier 60 would then pass the light through a first light splitting circuit 62 and then again perhaps to another light splitting circuit 64. The output of the splitter 64 would then be provided to WDM 58.

Also as shown, multiplexed telephone service POTS at the DS1 level (i.e. information from up to 24 telephone customers) on copper wire 65 is provided to distribution box 52 wherein the electrical telephony signals typically having a frequency band up to about 60 KHZ are provided to another laser diode 66. These electrical signals are then provided to laser diode 66 to modulate light having a wavelength of 1310 nanometers. This light is provided to optical fiber 54 as shown. As was discussed earlier, telephone service is typically TCM (time compression multiplexing) so as to provide for bidirectional communication at a single wavelength of light. Therefore as shown, light traveling upstream and leaving optical fiber 54 is directed toward a photo or a light detection diode 68 which is connected to a first recovery circuitry 70 (which according to this embodiment is a POTS recovery circuit) and a second recovery circuitry 72 (which according to this embodiment is an RF return recovery circuit).

As will be discussed in more detail later, the photodiode 68 receives the light and then according to the teachings of this invention the first recovery circuit 70 (POTS recovery circuitry) extracts the telephony signals having a frequency of about 3 MHz or less and the second recovery circuitry 72 extracts the RF return signals. Both sets of signals are received from the 1310 nanometer light. It should also be understood that the present invention is equally applicable to light having different wave lengths.

The input electrical signal to laser diode 66 on line 65 and the POTS output electrical signal from the first recovery circuitry 70 on line 74 actually represent a typical pair of twisted wires 71 used in normal POTS telephony service.

The 5-50 MHz RF return signals from the second recovery circuitry 72 and which has an output on line 78 is provided to a combining circuitry 80 which receives other similar signals from other TV customers up to a total of at least 16 (8+8) customers. The output of combining circuitry 80 is then provided to an 8 bit 90 MSPS (megsamples per second) analog-to-digital converter 81. The digital signals from A/D converter 81 are then provided to a 90 MHz 8 bit to 12 bit adder 82. Added 82 as shown can receive the output from 8 A/D converters such as A/D converter 82. Thus, it will be appreciated that the output from adder 82 going to the parallel to serial converter 84 will be carrying information related to at least 128 TV customers (16x8). The output of the P/S converter 84 may then provided to another E/O (electrical-to-optical) device 86 operating at 1 Gbps (giga bit per second). This output may then be transmitted by optical fiber 87 to CMTS (cable modem transmission source) at location 88 where the TV signal source 10 is also located. The light traveling through optical fiber 87 is then received by O/E (optical-to-electrical) converter 89 and the resulting electrical signals are provided to S/P (serial-to-parallel) converter 90. This parallel digital information is then provided to D/A converter 92, which in turn provides an analog signal to the TV signal source 10. This analog signal may of course be a control signal or other information related to a specific TV customer or subscriber.

Referring now to FIG. 4B, optical fiber 42 is shown being received at distribution panel 20. As shown optical fiber 42 is carrying television signals in one direction downstream by light having a wavelength of 1550 nanometers at the same time it carries bidirectional telephone communications using TCM (time compression multiplexing) by light having a wavelength of 1310 nanometers. As shown, the light having a wavelength of 1550 nanometers is directed towards a photodetector 94 which extracts the electrical television signals having a bandwidth of between 50 and 860 MHz. These electrical television signals are then provided by coaxial cable 96 to a diplex circuit 98 which has an output 100 provided to splitting circuit 102. Also as shown and as will be discussed hereinafter diplex circuit 98 also separates out electrical signals having a frequency of between 5 and 50 MHz traveling in the opposite direction. One of the outputs of splitter or distribution circuit 102 carrying the 50 to 800 MHz electrical signals will then be provided to building or house 22 by means of coaxial cable 12B in the manner previously discussed. The television signals on coaxial cable 12B are then either provided to TV set 20 or to another TV-signal using device such as set-top box 28, and then to TV set 26. Also, in the building 22 there is shown a computer 104 connected to a computer modem 34 as was discussed heretofore with respect to FIG. 1 and which is also connected to the standard telephone lines or POTS lines 32B. Also as shown, a telephone 30B is connected to the POTS lines 32B. The RF return or TV related signals sent back to the TV source location 10 may result from several sources. One possible source is for the set-top box 28 to sense that the television signals being received need to be either decreased or increased in amplitude or strength. Alternately, it may be that the customer or user of the television decides to purchase a particular pay-on-demand movie. Still another source of information may be an input from the computer 104 provided to the set-top box carrying information or requesting information. Such information must be provided back to the TV source location 10. Set-top box 28 will convert the information into an electrical signal having a frequency band of between 5 and 50 MHz which is inserted on coaxial cable 12B and transmitted to distribution terminal 20. It will be appreciated that coaxial cable 12B can carry information in both directions if the frequency band for the two directions is sufficiently separated. The 5-50 MHz television related signals are then routed to the diplex circuitry 98 where the electrical signals having a frequency band of 5 to 50 MHz are split out and provided to another combining multiplexing circuit 106.

Now referring again to the input cable 42 which, in addition to carrying light having a wavelength of 1550 nanometers as was previously discussed, is also carrying light at 1310 nanometers for the bidirectional telephone communication using TCM (time compression multiplexing) . Thus, the light having a wavelength of 1310 nanometer is provided to a photodetector 108 which extracts the telephony signals from the 1310 nanometer light traveling downstream. This signal leaves photodetector 108 on wires 109. These telephony electrically signals will typically be POTS signals at the DS1 (up to

24 customers) or DS2 (up to 96 customers) level and are provided to the multiplexer 110 and eventually by means of wires 32B to the telephone circuitry in house or building 22. It should be appreciated that the wire 32B connecting home 22 to the distribution panel 20 is a normal twisted pair of telephone wires. The upstream traveling POTS service travels on wire 111 to multiplex circuit 106 where it is combined with the 5 to 50 MHz RF return signals and provided on output line 112 to a laser diode 114 which generates light around a center frequency of about 1310 nanometers. Laser diode 114 then modulates the 1310 nanometers light with the electrical signals carrying the 5 to 50 MHz television related signals as well as the telephony signals. This light is then coupled to an optical fiber 42. Thus, as was discussed earlier, the fiber optic 42 carries the upstream traveling 1310 nanometer light to distribution panel 18 where it is split out for both telephony service and television related signal service.

Referring now to FIG. 5, there is shown a simplified block diagram to aid in understanding the basic concepts of the present invention. As shown, a photodiode 68 receives light and generates a common current between its cathode and anode. First recovery circuitry 70 and a corresponding load is connected to the cathode of photodiode 68, and also to a power source 69 which in turn is connected to ground. In a similar manner, a second recovery circuit 72 and a corresponding load is connected between the anode of photodiode 68 and ground. As will be discussed in detail hereinafter, the concepts of this invention are particularly useful for recovering POTS (telephone) signals which are transmitted at a frequency less than 3 MHz and RF return signals which typically will have a frequency of between 5 and 50 MHz. However, the first recovery circuit 70 could be designed to recover any selected frequency band which is distinct from the frequency recovered by the second recovery circuit 72 such as, for example, a frequency range of 50 MHz to 870 MHz. Similarly, second recovery circuitry could also be adjusted to recover another frequency band such as, for example, a frequency range of between 950 MHz to 2050 MHz. The important consideration is that the signals recovered by the first recovery circuit 70 should see a very low or substantially zero impedance across second recovery circuit 72, and the signals recovered by second recovery circuit 72 should see a very low or substantially zero impedance across the first recovery circuit 70.

Referring now to FIG. 6, there is shown circuitry for one preferred embodiment of the present invention. As shown, the first recovery circuitry 70 is connected to the cathode 116 of photodiode 68, by line 118 for recovering the POTS signals. When photodiode 68 is exposed or receives light 119 having a wavelength centered around 1310 nanometers a current flows from the cathode 116 of photodiode 68 to the anode 120. Therefore, since line 118 is connected to the "negative" or inverting input 122 of amplifier circuit 124, a signal will appear at output 126, since the "positive" or non-inverting input 128 is connected to a negative (-12) volt bias 130. It should also be noted that the positive terminal of a power source 132 is connected to ground 130 and the positive terminal of power source is connected to the low or V- power input 134 of amplifier unit 124. Power source 132 is represented as a battery in FIG. 5, but it will be appreciated by those skilled in the art that any type of power source that can provide the necessary voltage and current requirement would be satisfactory as power source 132 or any of the other power sources discussed below. A second power source 136 has its negative terminal connected to ground 30 and its positive terminal connected to the high side or V+ power input 138. A typical feedback loop comprised of a resistor 140 and capacitor 142 is connected between the output 126 and negative or inverting input 122 or amplified circuit 124. A typical low-pass filter 144 is connected between bias 130 and amplifier circuit output 126. In the embodiment shown in FIG. 5, low-pass filter 144 is comprised of a pair of inductors 146 and 148, capacitors 150, 152, and 154, and an input resistor 156. The value of these components is selected to pass signals within the frequency of 0-3 MHz. The output is on line 74 as shown. It is important to note that in this embodiment, since relatively low frequencies are being received, the use of a transformer can be avoided. However, if first recovery circuit 70 is used to recover much higher frequencies such as between 50 MHz to 870 MHz, then the circuitry of first recovery circuit 70 would be similar to that used in second recovery circuit 72 discussed below. The difference being the band-pass filter discussed below could be designed for the 50 MHz to 870 MHz range rather than 5 MHz to 50 MHz as set forth in the described embodiment.

The RF return recovery circuitry 72 is connected to the cathode 120 of photodiode 68 by input line 160. Also as shown, the cathode 120 is connected to negative bias 130 through inductor 162. Input line 166 is connected to a transformer 164 through a capacitor 168. Capacitor 168 and transformer 164 may be selected to respond to relatively high frequencies of between about 3 MHz and 100 MHz without any concern given to lower frequencies since the lower frequencies are recovered by the POTS recovery circuitry 70 connected to the cathode and photodiode 68. The high side of the secondary of transformer 164 is connected to the "negative" or inverting input 170 of amplifier 172 through capacitor 174 and resistor 176. Thus, the capacitor 168, transformer 164, capacitor 174, and resistor 176 operate together as a high-pass filter 170 suitable for passing signals within the frequency band of between 3 MHz and at least 50 MHz as indicated by dotted line. It will be appreciated that although it is important that band-pass filter 178 pass signals having a frequency of around 50 MHz, since there should be no signals of any significant strength above 50 MHz to assure good response at the 50 MHz frequency, the filter may conveniently be designed to pass frequencies higher than 50 MHz such as, for example, 100 MHz. The output of high-pass filter 178, as discussed above is connected to the "negative" or non-inverting input 170 of amplifier 172. Amplifier 172 is connected to reference voltage sources 180 and 182 in the same manner as voltage sources 132 and 136 were connected to amplifier 124 of the POTS recovery circuit 70 and operates substantially the identical way, except it is amplifying signals at higher frequencies. The output 184 is connected through a feedback section 186 and to RF return output line 78.

However, as was discussed above with respect to first recovery circuit 70, second recovery circuit 72 may also be designed to recover a different range of frequencies, such as between 950 MHz to 2050 MHz, by redesigning band-pass filter 178 to pass the selected higher frequencies.

Thus, there has been discussed to this point new and novel apparatus and methods for extracting two distinct and isolated frequency bands from light having a selected center frequency.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed.

WHAT IS CLAIMED IS:

1. A method of extracting two frequency bands from a photodiode receiving light of a selected wavelength comprising the steps of:

exposing a photodiode to light carrying signals at first and second frequency bands and having a selected wavelength;

amplifying a first output generated at a cathode of the photodiode in response to the light;

filtering the first output to recover signals at the first frequency band;

filtering a second output generated at an anode of the photodiode in response to the light to recover signals at the second frequency band;

amplifying the signals at the second frequency band; and

maintaining isolation of circuitry between the anode and the cathode of the photodiode.

2. The method of claim 1 wherein filtering the first output includes providing a low-pass filter which passes frequencies less than substantially about 3 MHz.

3. The method of claim 2 wherein filtering the second output includes providing a high-pass filter which passes frequencies greater than about 3 MHz.

4. The method of claim 1 wherein filtering the first output includes providing a band-pass filter which passes frequencies of between about 50 MHz and about 870 MHz.

5. The method of claim 4 wherein filtering the second output includes providing a band-pass filter of between about 950 MHz and 2050 MHz.

6. A method of extracting signals having first and second frequency bands from a photodiode exposed to light having selected wavelengths of light and carrying said first and second frequency bands comprising the steps of:

modulating said selected wavelength of light with a first signal having a first frequency band and with a second signal having a second frequency band, said first frequency band comprising frequencies which are less than said second frequency band;

exposing a photodiode to said selected modulated wavelength of light;

detecting signals at one of said first and second frequency bands at the cathode of said photodiode by first amplifying and then filtering an output at said cathode; and

detecting the other one of said first and second frequency bands at the anode of said photodiode by first filtering and then amplifying and output at said anode.

7. Apparatus for extracting signals at first and second bandwidths from a photodiode exposed to selected wavelengths of light comprising:

a photodiode having a cathode and an anode, said photodiode generating a current therethrough in response to light having substantially said selected wavelength;

a first detection circuit connected to said cathode for monitoring said current generated by said photodiode and for detecting signals within a first frequency band, said first detection circuit including an amplifier operable to amplify a first output generated at said cathode of said photodiode in response to said light, said first detection circuit operable to filter said first output to recover signals at said first frequency band; and

a second detection circuit connected to said anode for monitoring said current generated by said photodiode and for detecting signals within a second frequency band different than said first frequency band, said second detection circuit including a filter operable to filter a second output generated at said anode of said photodiode in response to said light to recover signals at said second frequency band, said second detection circuit including an amplifier operable to amplify said signals at said second frequency band, said first and second detection circuits substantially isolated from each other except through said diode.

8. The apparatus of claim 7 wherein each of said first and second detection circuits includes a band-pass filter and an amplifier.

9. The apparatus of claim 8 wherein the band-pass filter of said first detection circuit is a low-pass filter and said band-pass filter of said second detection circuit is a high-pass filter.

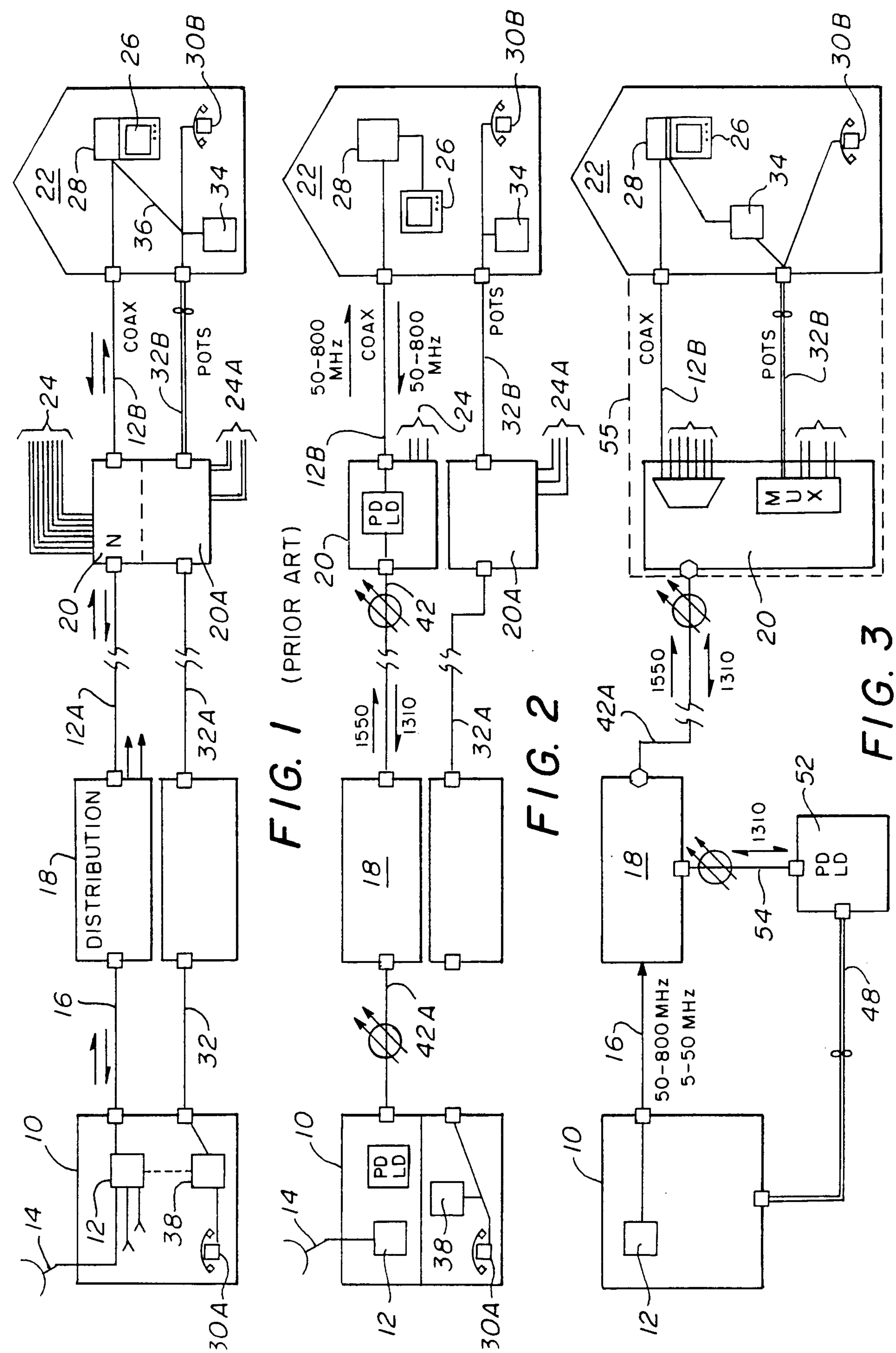
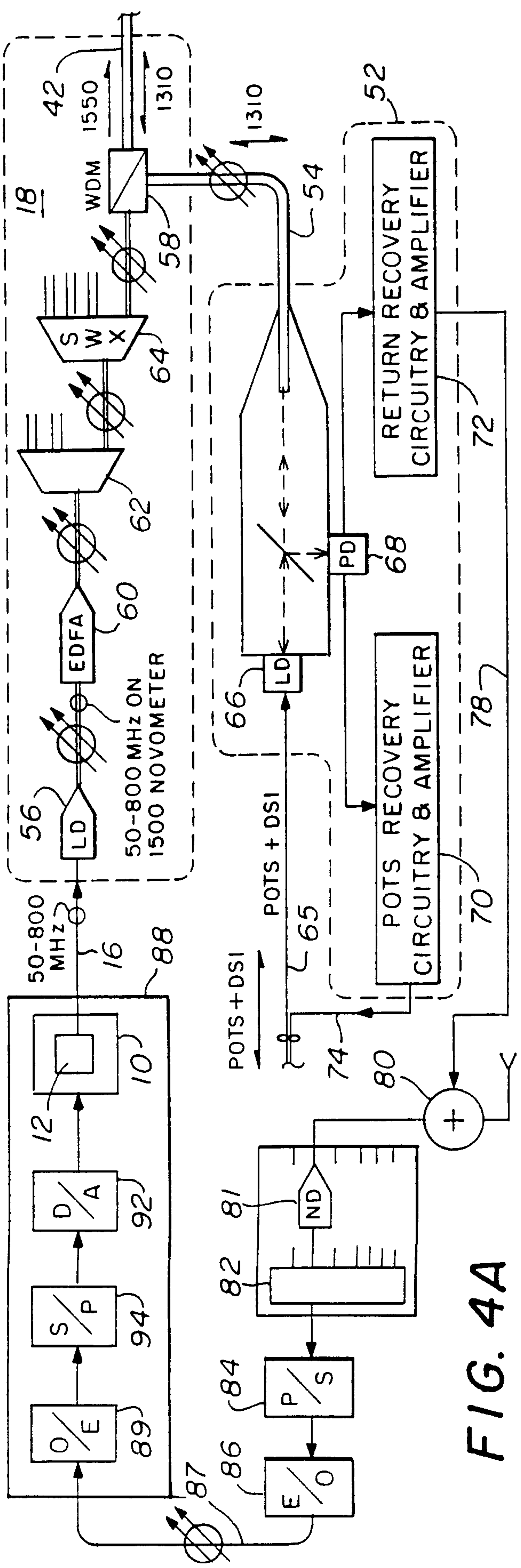


FIG. 1 (PRIOR ART)

FIG. 2

FIG. 3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EDFA
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62
S
W
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WDM
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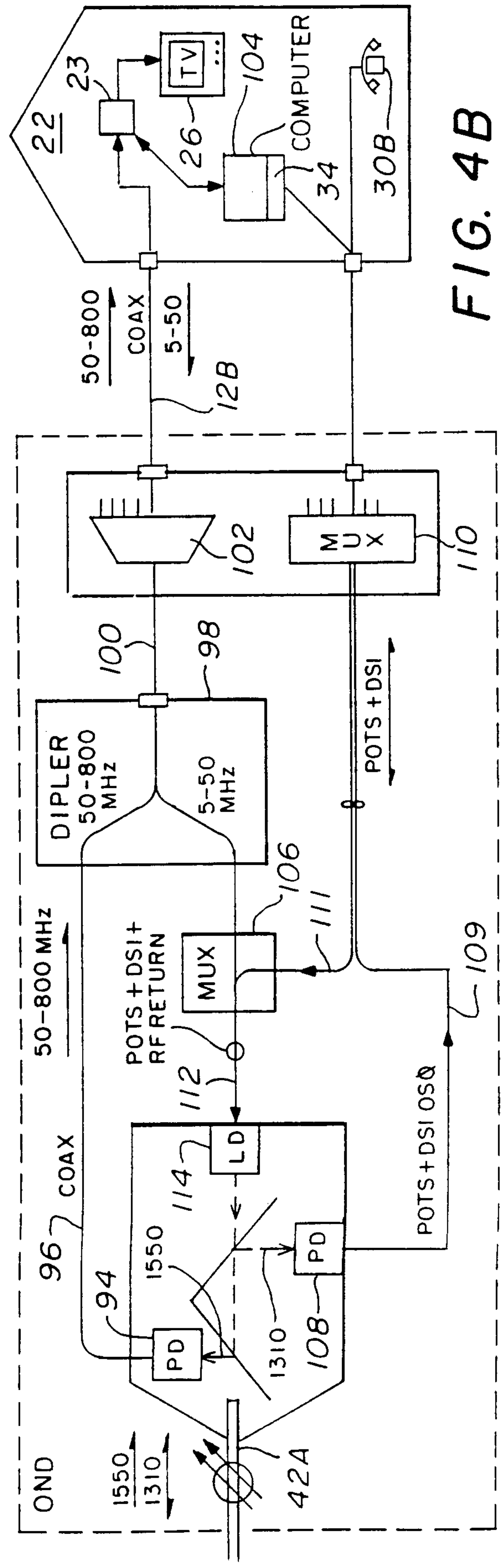
54
52
RETURN RECOVERY
CIRCUITRY & AMPLIFIER
72
PD
68
LD
66
78
POTS RECOVERY
CIRCUITRY & AMPLIFIER
70
POTS + DSI
65
74
80
50-800
MHz
16
88
10
12
D/A
92
S/P
94
O/E
89
ND
81
82
P/S
84
E/O
86
87

FIG. 4A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34
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COAX
5-50
12B
102
MUX
110
100
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50-800
MHz
5-50
MHz
106
MUX
111
POTS + DSI
POTS + DSI +
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109
112
LD
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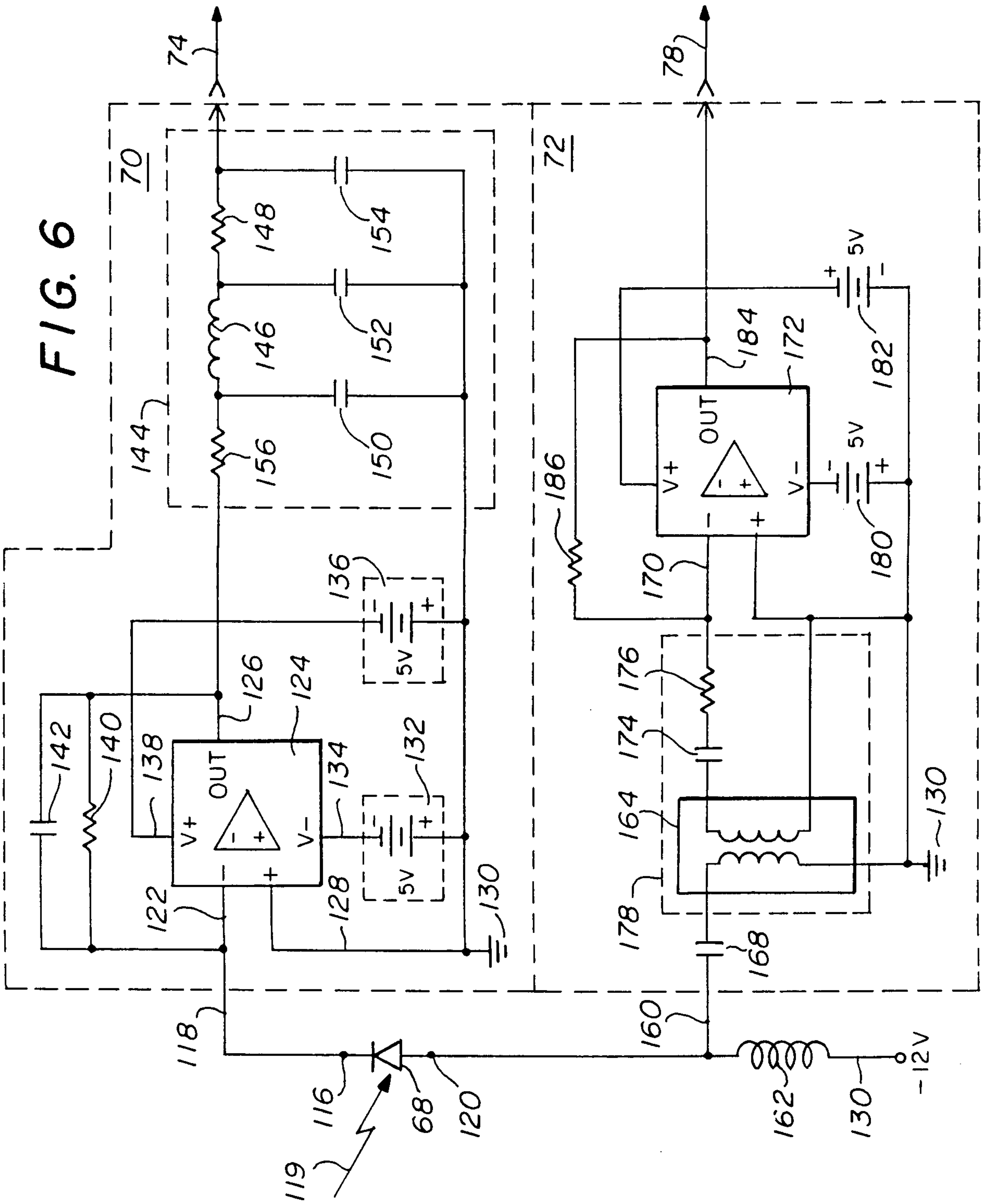
1310
42A

FIG. 4B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78
70
72
144
148
146
156
154
152
150
OUT
V+
V-
5V
136
126
124
142
140
138
134
132
122
128
130
118
116
68
120
119
160
162
-12V
186
184
172
182
180
170
176
174
164
178
168

FIG. 6

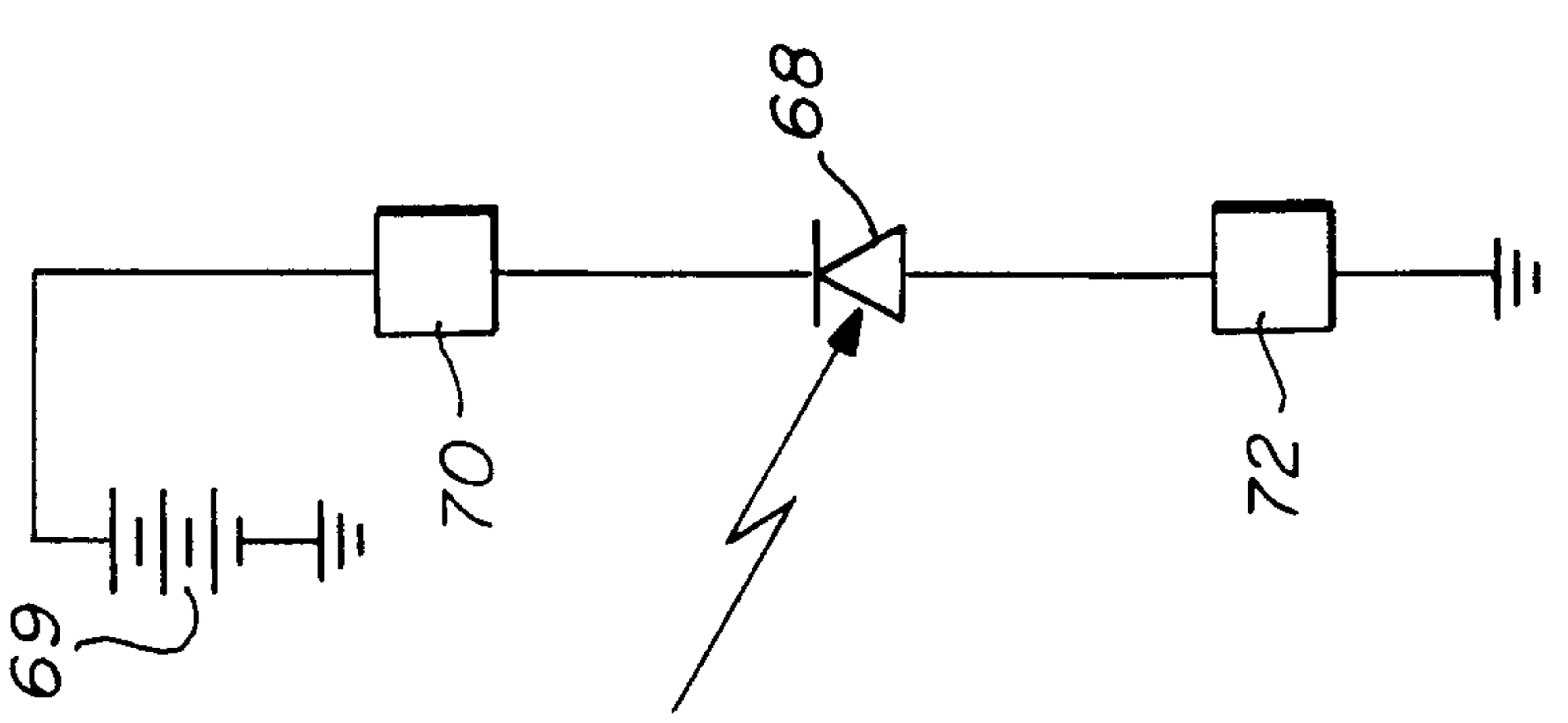
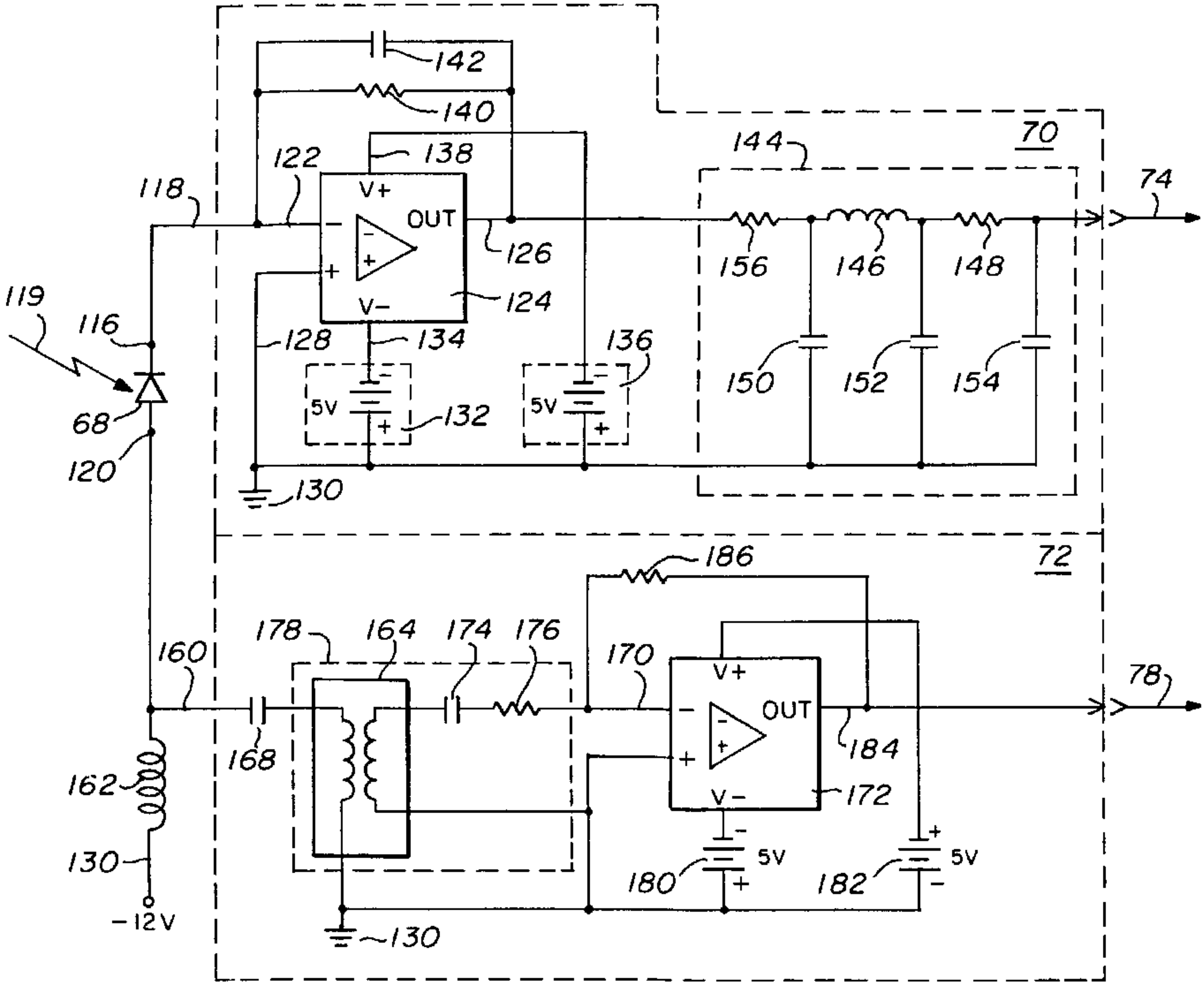

68
69
70
72

FIG. 5



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140
138
122
118
V+
OUT
126
124
V−
119
116
128
134
136
5V
132
68
120
130
144
70
74
156
146
148
150
152
154
186
72
178
164
174
176
170
160
OUT
78
184
168
162
172
180
5V
182
−12V