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(54) Title: HANDLING AUDIO SIGNALS

(57) Abstract: A system received an analogue electrical signal having content between 20 Hz and 20 kHz representing an analogue audio signal; pulse width or pulse density modulates the analogue electrical signal onto an optical signal; transmits the modulated optical signal over an optical waveguide; receives the modulated optical signal; and demodulates the modulated optical signal to reproduce the analogue electrical signal. The system may be incorporated within a cable arrangement.

# Handling Audio Signals

## Field Of The Invention

This invention relates to handling audio signals.

## Background To The Invention

In a concert environment, it is usual to connect sound sources, including guitars and microphones, to amplification equipment with shielded electrical cables. Such cables have a copper core and a metallic shield separated by an insulating material. At each end, a jack or plug, typically ¼ inch (0.635 mm) diameter, allows both the copper core and the shielding of the cable to be electrically connected to electronic circuitry in the relevant electrical equipment. Signals are carried from the sound source in the same form in which they are generated, i.e. as analogue signals in the audible frequency range 20 Hz to 20 kHz. In a studio environment, the same type of cable connects sound sources to mixing desk equipment. Cables used in concert environments can be over 10m long, although shorter cables tend to be used in studio environments.

Such cables can become internally damaged during use, especially when being used in an on-stage environment, although they may appear externally to be undamaged. Damaged cables cause a reduction in the quality of signals being carried, often resulting in unwanted distortion or other degradation of the audio signals. If the core of the cable becomes fractured, the cable can stop functioning altogether, although signal deterioration is more common. The inventor considers that signal degradation might result from fractures in the core and/or shielding and/or from damage to the insulating material separating the core from the shielding resulting in unwanted inductances and/or capacitances, which can cause unwanted resonance and/or filtering when supplied with energy in the form of the audio signals being carried.

The effects of cable damage can be avoided through the use of radio links between the sound source and the mixing desk or amplification equipment. Radio microphones are well known. However, the possibility of radio interference means that digital communication links are more reliable. However, musicians and sound producers prefer audio signals not to be digitised at any point in their transmission since this necessarily results in a reduction in quality, as well as a sound which subjectively is less pure.

It is an aim of the present invention to mitigate the above-mentioned disadvantages.

**Summary Of The Invention**

According to a first aspect of the present invention there is provided an audio signal communication system comprising:

an input for receiving an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

a modulator for pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal;

a transmitter for transmitting the modulated optical signal over an optical waveguide;

a receiver for receiving the modulated optical signal; and

a demodulator for demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20Hz and 20kHz.

By pulse width modulating or pulse density modulating the audio signals onto an optical signal for transmission, the invention avoids the need to sample the signals, thereby retaining signal quality and purity, whilst eliminating the possibility of the audio signals being subjected to unwanted capacitances and inductances during communication.

The invention also allows time delay, or lag, which can traditionally occur when digitising signals for transmission, to be avoided. This is advantageous since time delay, or lag, can be of annoyance to musicians in studio recording and in live performance situations.

A second aspect of the invention provides a cable arrangement comprising first and second devices connected by an optical waveguide, the first device comprising:

an electrical connector for coupling to a sound source thereby to receive an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

a modulator for pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal;

a transmitter for providing the modulated optical signal to the optical waveguide;

the optical waveguide being arranged to carry the modulated optical signal to the second device; and

the second device comprising:

a receiver for receiving the modulated optical signal from the optical waveguide;

a demodulator for demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20 Hz and 20 kHz; and

an electrical connector for mating with an audio signal receiving device, thereby to provide the audio signal receiving device with the analogue electrical signal.

A third aspect of the invention provides apparatus for communicating an audio signal, the apparatus comprising:

an input for receiving an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

a modulator for pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal; and

a transmitter for transmitting the modulated optical signal over an optical waveguide.

A fourth aspect of the invention provides apparatus for providing an audio signal, the apparatus comprising:

a receiver for receiving a pulse width or pulse density modulated optical signal; and a demodulator for demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20 Hz and 20 kHz.

A fifth aspect of the invention provides a method of communicating audio signals, the method comprising:

receiving an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal;

transmitting the modulated optical signal over an optical waveguide;

receiving the modulated optical signal; and

demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20 Hz and 20 kHz.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings.

**Brief Description Of The Drawings**

In the drawings:

Figure 1 is a schematic drawing of circuitry used to provide a pulse width modulated optical signal from an electrical audio signal, according to certain aspects of the invention;

Figure 2 is a schematic drawing of circuitry used to provide an electrical audio signal from a pulse width modulated optical signal, according to certain aspects of the invention;

Figure 3 is a schematic drawing of circuitry used to provide a pulse density modulated optical signal from an electrical audio signal, according to certain aspects of the invention;

Figure 4 is a schematic drawing of circuitry used to provide an electrical audio signal from a pulse density modulated optical signal, according to certain aspects of the invention;

Figure 5 is a schematic drawing of an audio signal communication cable embodying the invention;

Figure 6 is a schematic drawing of a guitar including the Figure 1 or Figure 3 circuitry and embodying the invention;

Figure 7 is a schematic drawing of a microphone including the Figure 1 or Figure 3 circuitry and embodying the invention; and

Figure 8 is a schematic drawing of a mixing desk or alternative amplification equipment including the Figure 2 or Figure 4 circuitry and embodying the invention

**Detailed Description Of The Preferred Embodiments**

Referring to Figure 1, an optical transmitter circuit 10 is shown schematically. The circuit 10 includes an input 11 which is connected to an impedance matching circuit 12. The input 11 may be a mechanical connector or may be some other electrical input. As is described in relation to Figure 5 below, the input 11 may be a ¼" jack. The signal conditioning circuit 12 has an input impedance matched to the output impedance of the source to which the input 11 is connected. The signal conditioning circuit 12 has an output impedance matched to the input impedance of a comparator 13, to which the signal conditioning circuit 12 is connected. The signal conditioning circuit 12 may be described as an impedance matching circuit.

Another input of the comparator 13 is connected to receive a signal from a ramp generator 15. The ramp generator 15 provides a sawtooth signal. The frequency of the signal determines the pulse width modulation (PWM) transmission speed. The frequency of the ramp signal provided by the ramp generator 15 is selected so as to be sufficiently high that it covers the entire dynamic range of audio signals up to 20,000 Hz. Inherently in its operation, the comparator 13 provides an amount of low pass filtering. The cut-off frequency depends on the ramp signal frequency. The comparator 13 compares the signal provided by the signal conditioning circuit 12 to the signal provided by the ramp generator 15 and provides a signal dependent on the comparison to a diode driver 14. The comparator 13 is operable continuously to compare the signals received at its two inputs, and the output signal at any given time is the result of a comparison of instantaneous signal levels at the two inputs. The output of the comparator is a logic 1 or a logic 0 signal depending on whether the level of the output signal of the signal conditioning circuit 12 is greater than or less than the level of the ramp signal provided by the ramp generator 15.

The diode 14 is switched by the output signal of the comparator 13. When the output signal of the comparator 13 is a logic 1, the diode produces light at a relatively high intensity, and when the output signal of the comparator 13 is a logic 0, the diode 14 generates light at a relatively lower intensity. The resulting light is provided to an optical cable 16.

The signal conditioning circuit 12 does not effect any modulation or other processing of the signal received from the input 11. Thus, provision of audio frequency signals, i.e. signals in the range 20 Hz to 20,000 Hz, results in the comparator 13 comparing an audio frequency signal to the ramp signal provided by the ramp generator 15. Thus, the output signal of the comparator 13 comprises a pulse width modulated signal at audio baseband. It can be said that the baseband audio signal is modulated directly onto the optical signal. Put another way, aside from the modulation effected by the pulse width modulator comprising the comparator 13 and the ramp generator 15, no other modulation is applied to the audio frequency signal received at the input 11.

In tests, ramp signal frequencies of between 250 kHz and 1 MHz have been found to be effective whilst providing suitably low power consumption.

Referring to Figure 2, an optical receiver will now be described. The optical receiver 20 includes a photo receiver 21 connected to the optical cable 16 of Figure 1. The photo receiver 21 comprises a photodiode or other device operable to convert a received light signal into an electrical signal. In this embodiment, no substantive signal processing is performed by the photo receiver 21.

A signal conditioning circuit 22 is connected to receive the output signal of the photo receiver 21. The signal conditioning circuit 22 is arranged to recover the received pulse width modulated pulses and amplify them to a predetermined peak signal level. The signal conditioning circuit 22 may comprise a simple comparator circuit operating to provide an output signal at two distinct voltages. The signal conditioning circuit 22 renders unimportant any reduction in the amplitude of the light signal as it is transmitted over the optical cable 16. However, the signal conditioning circuit 22 does not effect any appreciable change in the timings of the edges of pulses. This is important since it is the duration of the pulses that is important in a pulse width modulated system.

An output of the signal conditioning circuit 22 is connected to an input of a low pass filter (LPF) 23. The LPF 23 may comprise an RLC (resistance, inductance, capacitance) circuit. The LPF recovers the original audio signal, i.e. the audio frequency signal provided at the input 11 of the Figure 1 circuit. As each pulse of the pulse width modulated signal passes through the low pass filter, an average of that pulse acquires a value, and this value contributes to rebuilding the audio input signal.

An output of the LPF is connected to an output 25 via an impedance matching circuit 24. The input impedance of the impedance matching circuit 24 is matched to the output impedance of the LPF 23. The output impedance of the impedance matching circuit 24 is matched to the input impedance of the output 25, or a device which is anticipated to be connected to the output 25.

The output 25 may be for instance a ¼" jack, although it may instead take some other form.

The effect of the optical receiver 20 is to receive a pulse width modulated optical signal and to provide therefrom an electrical signal at audio frequencies and faithfully reproducing an audio signal received at the input 11 of the Figure 1 circuit. Because the signal is transmitted over the optical cable 16 as a pulse width modulated signal, there cannot be any signal loss between the optical transmitter circuit 10 and the optical receiver circuit 20. Even if there is attenuation of the optical signal provided by the diode 14, the optical receiver circuit 20 is able to reconstruct completely the audio frequency signal because the content is represented by the width of the pulses.

Moreover, the optical transmitter circuit 10 and the optical receiver circuit 20 operate on the audio frequency signal at baseband, and not at any higher frequencies, as would be experienced if another carrier was used. Thus, the arrangement of the circuits are relatively simple, inexpensive to manufacture and reliable in operation. Crucially, the low frequencies used by the optical transmitter circuit 10 and the optical receiver circuit 20 allows the use of low power components, which thereby allows the power consumption of each of the circuits to be relatively low. The use of pulse width modulation also means that there is no need for highly linear circuits either in the optical transmitter circuit 10 or the optical receiver circuit 20. Consequentially, the power consumption of the optical transmitter circuit 10 and the optical receiver circuit 20 is considerably less than the power consumption of corresponding arrangements which require the use of linear circuits or components in their operation. Low power consumption allows the arrangements to be powered by a battery. With suitable component choices, a relatively small capacity battery can provide many tens of hours of use.

Although pulse width modulation is used to communicate the audio frequency signal from the input 11 to the output 25, there is no digitisation of the signal. Thus, no quantisation noise is generated and, as long as a suitable frequency for the ramp signal is used, there is no appreciable loss in signal quality. Any loss in signal quality resulting from the Figures 1 and 2 arrangements is likely to be significantly less than loss of signal quality resulting from an ordinary electrical lead, as is conventionally used.

Referring now to Figure 3, an alternative optical transmitter circuit 30 is shown. The circuit includes an input 31, at which audio frequency signals, that is electrical signals between 20 Hz and 20,000 Hz, are received. As with the Figure 1 circuit, the input 31 may be a ¼" jack.

A signal conditioning circuit 32 is connected to the input 31. To the output of the signal conditioning circuit 32 is connected an input of a sigma delta modulator 33. The signal conditioning circuit 32 has an output impedance approximately equal to the input impedance of the delta sigma modulator 33, and has an input impedance substantially equal to the output impedance of the input 31 or a device to which the input 31 is expected to be connected. The purpose of the signal conditioning circuit 32 is to maintain single integrity and to prevent components of the optical transmitter circuit 30 from interfering with or altering the input signal. The signal conditioning circuit 32 may be termed an impedance matching circuit.

Another input of the delta sigma modulator 33 is connected to an output of a master clock 35. The master clock in this example has a frequency of 11.2896 MHz as a reference timing. This signal is divided down to 2.8224 MHz by circuitry within the delta sigma modulator 33. This reduction in the clock frequency, by a factor of 4, reduces timing fluctuations. Inherently in its operation, the delta sigma modulator 33 provides an amount of low pass filtering. The cut-off frequency depends on the clock frequency, but is about 100 kHz for a 2.8224 MHz clock signal.

The delta sigma modulator 33 uses the clock signal provided by the master clock 35 to produce a pulse density modulated (PDM) representation of the signal received from the signal conditioning circuit 32. Delta sigma modulators are known in the art. Briefly, the delta sigma modulator 33 uses negative feedback to process the signal such that if the instantaneous input signal, accumulated over one sampling period (a sampling period is the interval between successive cycles of the signal provided by the master clock 35) rises above the value accumulated in the negative feedback loop during previous samples, a converter outputs a logic value 1. If the waveform falls relative to the accumulated value, the converter outputs a logic value 0. A PDM signal comprising all logic value 1's indicates a signal at the maximum input voltage. A PDM signal comprising solely logic 0's indicates an input waveform at the maximum negative level. A sequence of alternating 1's and 0's represents a 0 V input signal. The proportion of 1's to 0's in a sequence of a PDM signal gives the average value of the input signal over the corresponding interval.

A diode driver 34 is connected to an output of the delta sigma modulator 33. The diode driver is a high-speed diode driver, such as a resonant cavity light emitting diode. Such diodes are currently available from Firecomms (www.firecomms.com) running at speeds of 400 Mbps (mega bits per second). Such diodes are very capable of correctly handling the 2.8224 MHz signal provided by the delta sigma modulator 33. It will be appreciated that the diode driver 34 includes a light emitting diode and driving circuitry. The diode driver 34 provides a PDM signal to an optical cable 36.

Referring now to Figure 4, a photo receiver 41 is arranged to receive the PDM signal received over the optical cable 36. A signal conditioning circuit 42 is connected between the photo receiver 41 and an input of a low pass filter (LPF) 43. The signal conditioning circuit 42 recovers the PDM pulses transmitted over the optical cable 36 and amplifies them to a fixed voltage signal. This removes any smoothing of the pulses resulting from transmission. The amount of smoothing, and thus the extent of the advantage provided by the signal conditioning circuit 42, depends on the type of optical cable 36 and on the components used in the diode driver 34 and the photo receiver 41. With suitable choices for the diode driver 34, the optical cable 36 and the photo receiver 41, the signal conditioning circuit 42 may be omitted.

The LPF 43 consists of an RLC (resistance, inductance, capacitance) circuit. The low pass filter recovers the original audio signal, being the audio frequency signal received at the input 31 of the Figure 3 circuit. As each 1 pulse of the PDM passes through the LPF 43, an average signal is created. Each positive pulse adds to the signal value, and each 0 pulse removes value from the signal. In this sense, the LPF 43 is very similar to the LPF 23 of the Figure 2 circuit. A suitable LPF is the DSD1700 produced by Burr-Brown.

Thus, the output signal of the LPF 43 comprises a pulse width modulated signal at audio baseband. It can be said that the baseband audio signal is modulated directly onto the optical signal.

An output of the LPF 43 is connected to an output 45 via an impedance matching circuit 44. The input impedance of the impedance matching circuit is matched to the output impedance of the LPF 43, and the output impedance of the impedance matching circuit is matched to the input impedance of the output 45, or a device to which the output 45 is expected to be connected. Impedance matching helps to maintain signal integrity.

The use of PDM extends the audio frequency range by an amount dependent on the clock signal frequency. Using a 2.8224 MHz signal, the audio range is extended to 100 kHz. Moreover, there is no "brick wall" filter at just over 20 kHz that is needed to make effective numerous prior art audio signal handling systems.

As with the Figures 1 and 2 circuits, the input 31 and the output 45 may be ¼" jacks, although they may take some other form.

The Figures 3 and 4 circuits provide pulse density modulation transmitter and receiver circuits which communicate the audio frequency signal without any additional modulation, i.e. at baseband, over the optical cable 36.

The effect of the optical receiver 40 is to receive a pulse density modulated optical signal and to provide therefrom an electrical signal at audio frequencies and faithfully reproducing an audio signal received at the input 31 of the Figure 3 circuit. Because the signal is transmitted over the optical cable 36 as a pulse density modulated signal, there is no sampling of the input signal and thus no quantisation noise is generated. Furthermore, it is irrelevant whether there is any attenuation of the optical signal provided by the diode because the content is represented by logic 1 and logic 0 pulses which can accurately be reconstructed even in the presence of attenuation. Any loss in signal quality resulting from the Figures 1 and 2 arrangements is likely to be significantly less than loss of signal quality resulting from an ordinary electrical lead, as is conventionally used.

The arrangement of the optical transmitter circuit 30 and the optical receiver circuit 40 circuits are relatively simple, inexpensive to manufacture and reliable in operation. Furthermore, unlike in pulse code modulation systems, no expensive filtering is required. The PDM technique used by the optical transmitter circuit 30 and the optical receiver circuit 40 circuits is similar to that used by Sony's DSD, which is used in SACD. Crucially, the low frequencies used by the optical transmitter circuit 30 and the optical receiver circuit 40 allows the use of low power components, which thereby allows the power consumption of each of the circuits to be relatively low. The use of pulse density modulation also means that there is no need for highly linear circuits either in the optical transmitter circuit 30 or the optical receiver circuit 40. Consequentially, the power consumption of the optical transmitter circuit 30 and the optical receiver circuit 40 is considerably less than the power consumption of corresponding arrangements which require the use of linear circuits or components in their operation. Low power consumption allows the arrangements to be powered by a battery. With suitable component choices, a relatively small capacity battery can provide many tens of hours of use.

Figure 5 shows a cable arrangement 50 according to various aspects of the invention. A first part includes a first metallic ¼ inch jack 51 and a corresponding body 52. The jack 51 comprises the input 11 of the Figure 1 circuit 10. Within the body of the first jack is a first device 55 comprising the other components of the Figure 1 transmitter circuit 10 and a 3V battery. The circuit in the device 55 is connected to the first jack 51 so as to be able to receive analogue electrical audio frequency signals applied thereto. The diode 14 in the first device 55 is arranged so as to pass the light that it emits into an end of a shielded optical fibre 57, which is the optical cable 16 of Figure 1.

At an opposite end of the optical fibre 57, a second device 56 is included in a body of a second jack, which includes a second ¼ inch jack 54. The jack 54 is the output 25 of Figure 2. The second device 56 includes the other components of the Figure 2 circuit and a 3V battery. The photo receiver 21 in the second device 56 is arranged to receive light transmitted down the optical fibre 57. The electrical output of the second device 55 is provided to the second jack 54.

The cable arrangement 50 is used by mating the first jack into a signal out socket of a guitar or other sound source, and by mating the second jack 54 into a signal in socket of a mixing desk or amplification device or similar. When the guitar is played, analogue electrical audio frequency signals are provided to the conductors of the first jack, and thus are carried to the input of the transmitter circuit included in the first device 55. The first device 55 thus processes the audio signal into a PWM optical signal, which is transmitted along the optical fibre 57. The PWM optical signal is received at the second device 56, where the pulse width modulation is converted into an electrical analogue audio frequency signal and provided to the conductors of the second jack 54 and thus the amplification device or mixing desk that it is connected to. The signals produced by the audio source thus are carried to the amplification device or mixing desk without being digitised and without being transmitted along a shielded electrical cable.

In another embodiment, the Figures 3 and 4 circuits are provided as part of the devices 55 and 56 respectively. The description of the Figure 5 embodiment applies also to the PDM circuits of Figures 3 and 4.

A prototype of the PWM version of the Figure 5 cable arrangement 50 has been constructed. It was found that manual distortion of the prototype optical cable 57 results in no audible change in signal, since there is no signal degradation in the optical cable 57.

Since power consumption of the Figure 1 circuit is low, the batteries were able to power their respective circuits correctly for many tens of hours before requiring replacement. This is very advantageous since typically it would be inconvenient to replace or recharge batteries in a cable arrangement. However, using the invention, the interval between battery recharges or replacements is sufficiently long for most users.

The cable arrangement 50 suffers some disadvantages compared to the conventional electrical cable arrangement. In particular, a power supply is needed at each end of the cable arrangement, whereas this is not true of the electrical cable. Also, the cable arrangement 50 is unidirectional, and can carry audio signals only from the first jack to the second jack. As a result of this, it is considered that the two jacks should be visibly different from one another, for instance by the inclusion of arrows indicating the direction of signal transmission, or through the use of different patterning or colouring. The conventional electrical cable, on the other hand, is bidirectional.

A break in the optical cable would normally result in the ceasing of incorrect transmission, although such can also occur with conventional electrical cables.

Furthermore, since different sources have different output impedances, a different cable arrangement is needed for each different type of source in order to maintain optimal signal integrity. This contrasts to the conventional arrangement in which a given cable is useable with all different source types without affecting signal integrity.

Although these disadvantages can be considered to be quite significant, it is considered that the improvements in signal quality resulting from the invention outweigh the disadvantages.

It has been found that different audio sources produce different signal voltages. For instance, an electric guitar produces an output signal having a maximum swing of 3 or 4 Volts, whereas certain microphones produce only 50 mV or so. Whereas an amplitude or intensity modulated transmission arrangement would need to accommodate different input signal swings, the use of PWM gives rise to the advantage that many different signal swings are accommodated without requiring any modification.

Figure 6 illustrates schematically an electric guitar 60 according to aspects of the invention. The guitar includes three transducers, namely a neck humbucker 61, a middle coil 62 and a bridge humbucker 63. Each of these is connected to an electronic switching circuit 64, which includes controllable potentiometers. The switching circuit 64 provides electrical analogue signals at audio frequencies to a socket 67, with which a ¼ inch jack can be mated. The guitar thusfar described is conventional.

The guitar 60 also includes a circuit 65, which comprises the Figure 1 circuit 10. The circuit 45 is connected to receive electrical analogue signals at audio frequencies from the switching circuit 64. The circuit 65 is powered by a power source, such as a 3V battery (not shown) included in the guitar 60. The circuit 65 pulse width modulates the electrical analogue signal onto an optical signal and provides the result to an optical connector 66 mounted on a face of the housing of the guitar 60. An optical cable (not shown) is connectable into the optical connector 66, and carries the optical signal generated by the circuit 65 away from the guitar. Thus, the guitar 60 provides an optical pulse width modulated signal in the same way that a combination of a conventional guitar and the first jack of the Figure 5 cable arrangement 50 would provide. All of the benefits stated above with relation to the previous Figures apply to this embodiment. Since it includes an electrical signal output socket 67, the guitar 60 also is usable conventionally, although this can be omitted if not required.

Instead of the Figure 1 circuit, the guitar 60 may equally conveniently include the Figure 3 circuit.

Figure 7 illustrates schematically a microphone 70 according to aspects of the invention. The microphone 70 includes a microphone transducer 71, as is conventional. The microphone transducer is connected to a circuit 72, which comprises the Figure 1 circuit 10. The circuit 72 is powered by a battery 73. The circuit 72 is connected to receive electrical analogue signals at audio frequencies from the microphone transducer 71. The circuit 72 pulse width modulates the electrical analogue signal onto an optical signal and provides the result to an optical connector 74 mounted on a face of the housing of the microphone 70. An optical cable 75 is removably or fixedly connected into the optical connector 74, and carries the optical signal generated by the circuit 72 away from the microphone 70. Thus, the microphone 79 provides an optical pulse width modulated signal in a way similar to that of the Figure 6 guitar 60 or the Figure 1 transmit circuit 10.

Instead of the Figure 1 circuit, the microphone 70 may equally conveniently include the Figure 3 circuit.

Figure 8 shows an amplification device 80, commonly known as an amplifier. An integral power supply 83 receives mains electricity, and powers a conversion circuit 85 and an amplifier circuit 81. The amplifier circuit 81 is connected via a user-operable switch 87 selectively to receive an electrical analogue signal from an input socket 82 or to receive an electrical analogue signal from the conversion circuit 85. The conversion circuit 85 is as the Figure 2 circuit. It receives pulse width modulated optical signals through an optical cable (not shown) mated with an optical connector 84 included in a face of the housing of the amplifier 80. The amplifier circuit 81 amplifies the electrical it receives from the switch 87 and provides a low impedance power signal to a speaker 86, thereby to produce an audible signal based on the received signals. Thus, the amplifier 80 is operable to process received pulse width modulated optical signals and produce audio signals therefrom. The amplifier can be considered to be the second jack of the Figure 5 cable arrangement integrated with a conventional amplifier. The electrical connector 82 can be omitted if not required.

Figure 8 alternatively shows schematically components of a mixing desk 80, such as may be used in a studio to produce and record music. Here, an integral power supply 83 receives mains electricity, and powers a conversion circuit 85 and a low-power amplifier circuit 81. The amplifier circuit 81 is connected via a user-operable switch 87 selectively to receive an electrical analogue signal from an input socket 82 or to receive an electrical analogue signal from the conversion circuit 85. The conversion circuit 85 is as the Figure 2 circuit. It receives pulse width modulated optical signals through an optical cable (not shown) mated with an optical connector 84 included in a face of the housing of the mixing desk 80. The amplifier circuit 81 amplifies the electrical it receives from the switch 87 and provides a high impedance signal to sound processing/recording circuitry 86. Thus, the mixing desk 80 is operable to process received pulse width modulated optical signals and produce electrical representations of audio signals therefrom for processing and/or recording. The mixing desk 80 can be considered to be the second jack of the Figure 5 cable arrangement integrated with a conventional mixing desk. The electrical connector 82 can be omitted if not required.

Instead of the Figure 1 circuit, the amplifier 80 may equally conveniently include the Figure 4 circuit.

In an alternative embodiment, the Figure 2 receiver circuit or the Figure 4 receiver circuit is provided on an interface card (not shown) for connection to a computer. In this embodiment, the interface card includes a high quality digital-to-analogue converter for converting the demodulated audio signals into a digital signal, for processing and/or recording by a computer.

Although the above describes that the sound source can be a guitar or microphone, the sound source may be any other type that produces analogue audio signals. The invention has most advantage with sound sources which are moved around during a performance, since these are most likely to have electrical cables damaged during use.

An additional advantage is electrical isolation. Conventional cabling includes electrical conductors.

A ground loop exists when the Guitar amplifier and the microphone are on different earth (ground) terminals. For instance, it is known for guitarists to inadvertently use their bodies to effect balancing between a microphone earth and a guitar earth. Unfortunately, such often occurs through the mouth of the guitarist as they touch the microphone with their mouth whilst holding their guitar, with the resultant electrical shock.

Also, in the event of faulty amplification equipment, electrical power could be transferred through the cable to a guitar player or other person, potentially resulting in electrical shock. The same could occur in the event of a lightning strike, which are not uncommon at outdoors concerts and the like. Using an optical fibre to convey audio signals, on the contrary, provides electrical isolation between the ends of the cable, and thus provides improved safety.

The human ear is able to perceive audio signals between 20 Hz and 20 kHz, so it is normally only those signals that are of interest to a musician or sound producer. However, the carrying also of additional signal frequencies is not precluded by the invention, as long as the content of primary interest is in the audible frequency range.

The optical cable and the connectors may take any suitable form, for example one of the many components commonly available in electronic component shops.

A beneficial effect of pulse width modulating or pulse density modulating a baseband analogue audio signal onto an optical signal is that it allows time delay, or lag, which can traditionally occur when digitising signals for transmission, to be avoided. This is advantageous since time delay, or lag, can be of annoyance to musicians in studio recording and in live performance situations.

**Claims**

1. An audio signal communication system comprising:

an input for receiving an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

a modulator for pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal;

a transmitter for transmitting the modulated optical signal over an optical waveguide;

a receiver for receiving the modulated optical signal; and

a demodulator for demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20Hz and 20kHz.

2. A system as claimed in claim 1, comprising a signal conditioning circuit connected between the input and the modulator.

3. A system as claimed in either preceding claim, comprising an impedance matching circuit connected between the demodulator and an output.

4. A system as claimed in any preceding claim, in which the transmitter and the modulator are integrated into a device having an electrical connector for mating with a sound source.

5. A system as claimed in any of claims 1 to 3, in which the transmitter and the modulator are integrated into a device comprising a sound source.

6. A system as claimed in any preceding claim, in which the receiver and the de modulator are integrated into a device having an electrical connector for mating with an audio signal receiving device.

7. A system as claimed in any of claims 1 to 5, in which the receiver and the demodulator are integrated into an audio signal receiving device

8. A cable arrangement comprising first and second devices connected by an optical waveguide,

the first device comprising:

an electrical connector for coupling to a sound source thereby to receive an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

a modulator for pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal;

a transmitter for providing the modulated optical signal to the optical waveguide;

the optical waveguide being arranged to carry the modulated optical signal to the second device; and

the second device comprising:

a receiver for receiving the modulated optical signal from the optical waveguide;

a demodulator for demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20 Hz and 20 kHz; and

an electrical connector for mating with an audio signal receiving device, thereby to provide the audio signal receiving device with the analogue electrical signal.

9. Apparatus for communicating an audio signal, the apparatus comprising:

an input for receiving an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

a modulator for pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal; and

a transmitter for transmitting the modulated optical signal over an optical waveguide.

10. Apparatus as claimed in claim 9, integrated into a device comprising a sound source.

11. Apparatus for providing an audio signal, the apparatus comprising:

a receiver for receiving a pulse width or pulse density modulated optical signal; and

a demodulator for demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20 Hz and 20 kHz.

12. Apparatus as claimed in claim 11, integrated into an audio signal receiving device.

13. A method of communicating audio signals, the method comprising:

receiving an analogue electrical signal having baseband audio signal content between 20 Hz and 20 kHz;

pulse width modulating or pulse density modulating the baseband analogue audio signal onto an optical signal;

transmitting the modulated optical signal over an optical waveguide;

receiving the modulated optical signal; and

demodulating the modulated optical signal to produce an analogue electrical signal having audio signal content between 20 Hz and 20 kHz.

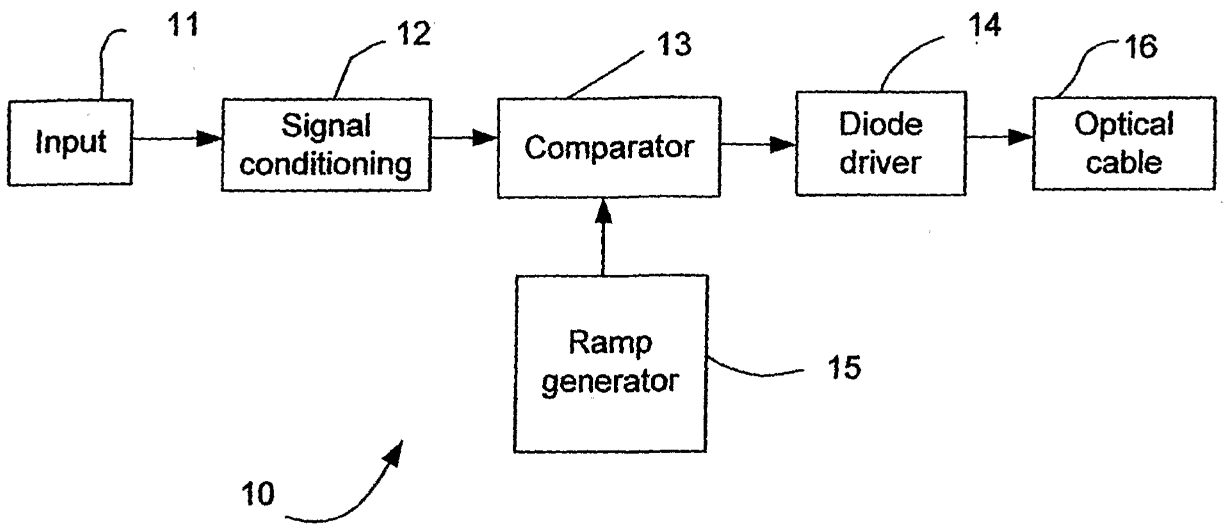


Figure 1

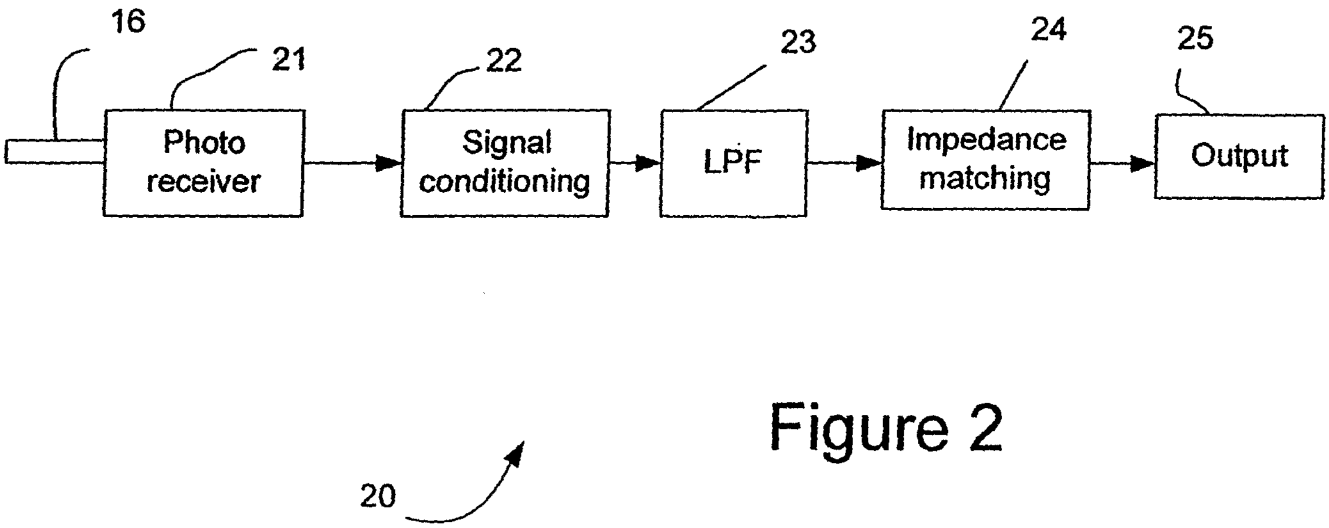


Figure 2

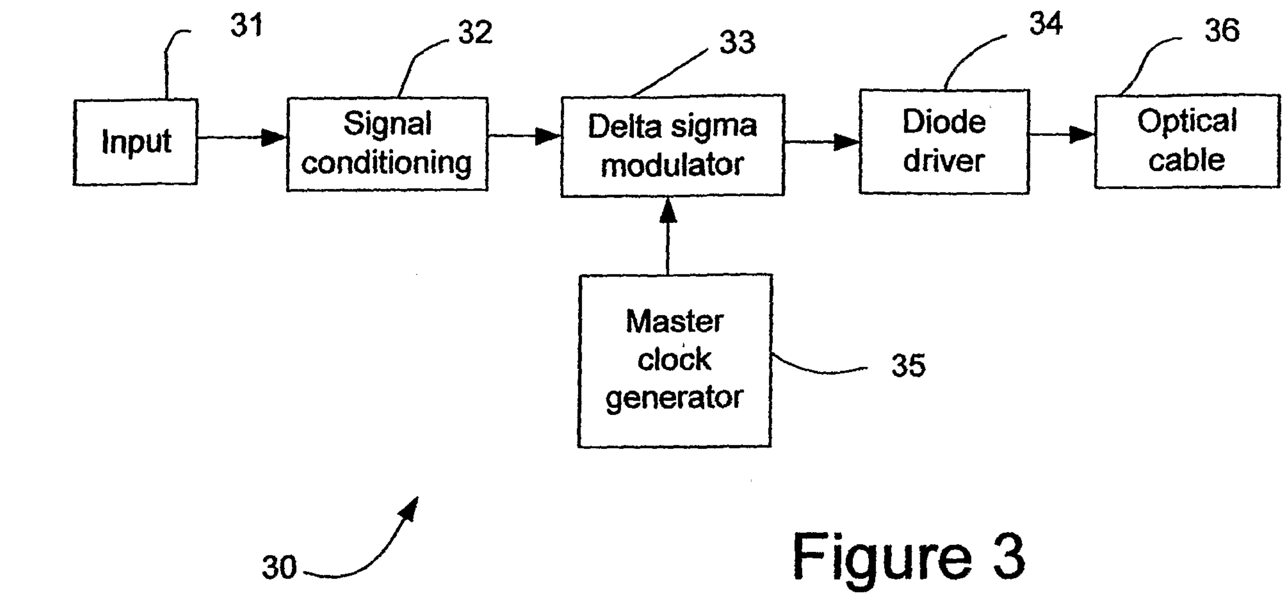


Figure 3

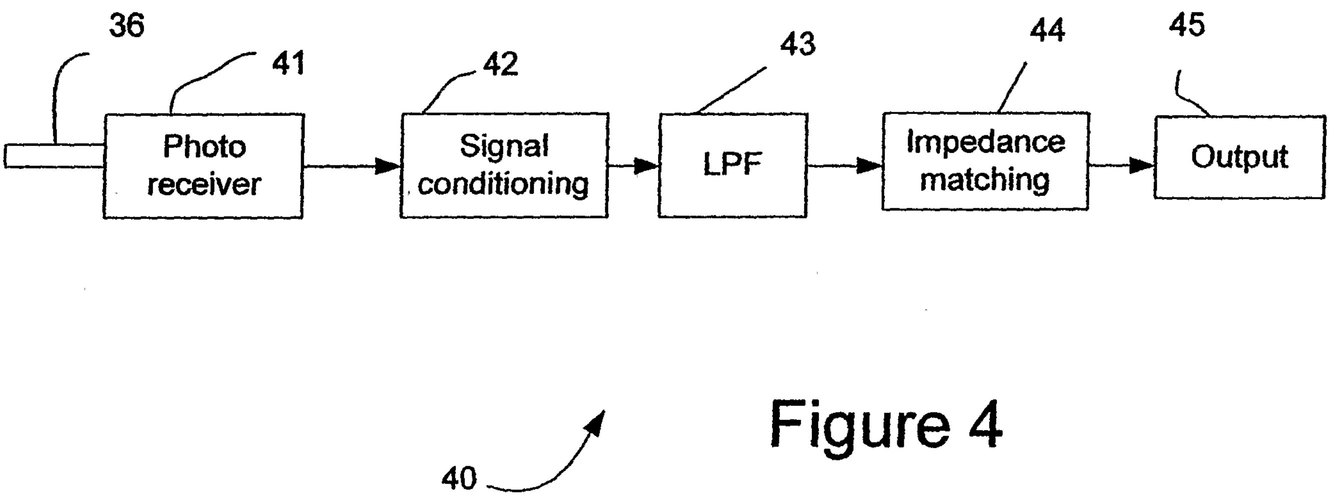


Figure 4

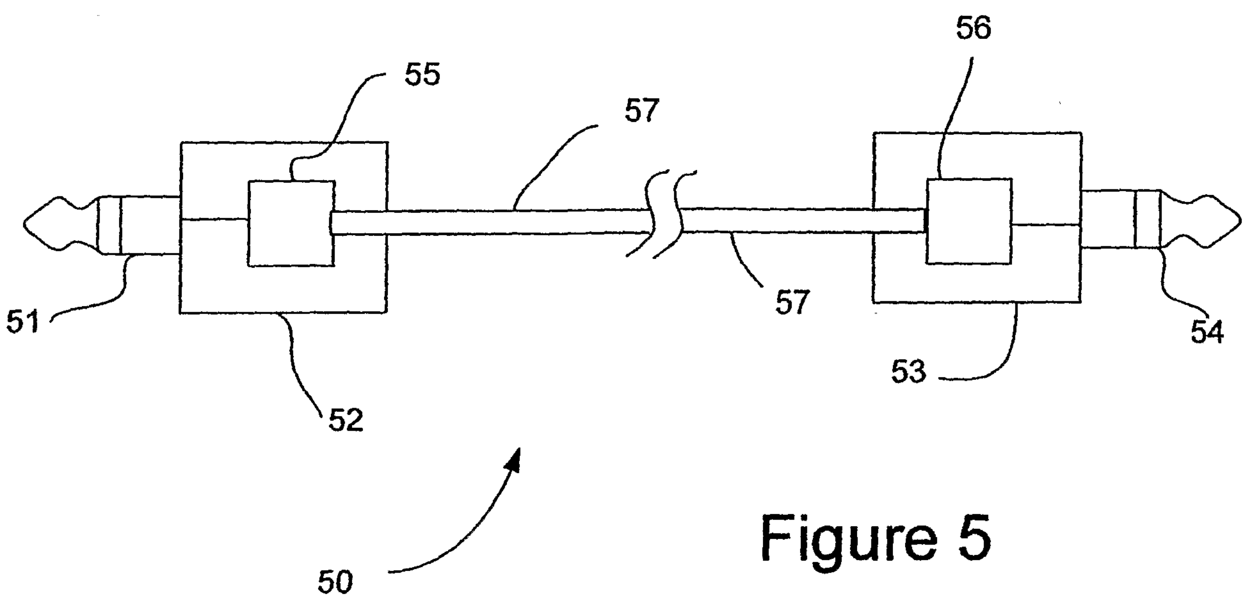


Figure 5

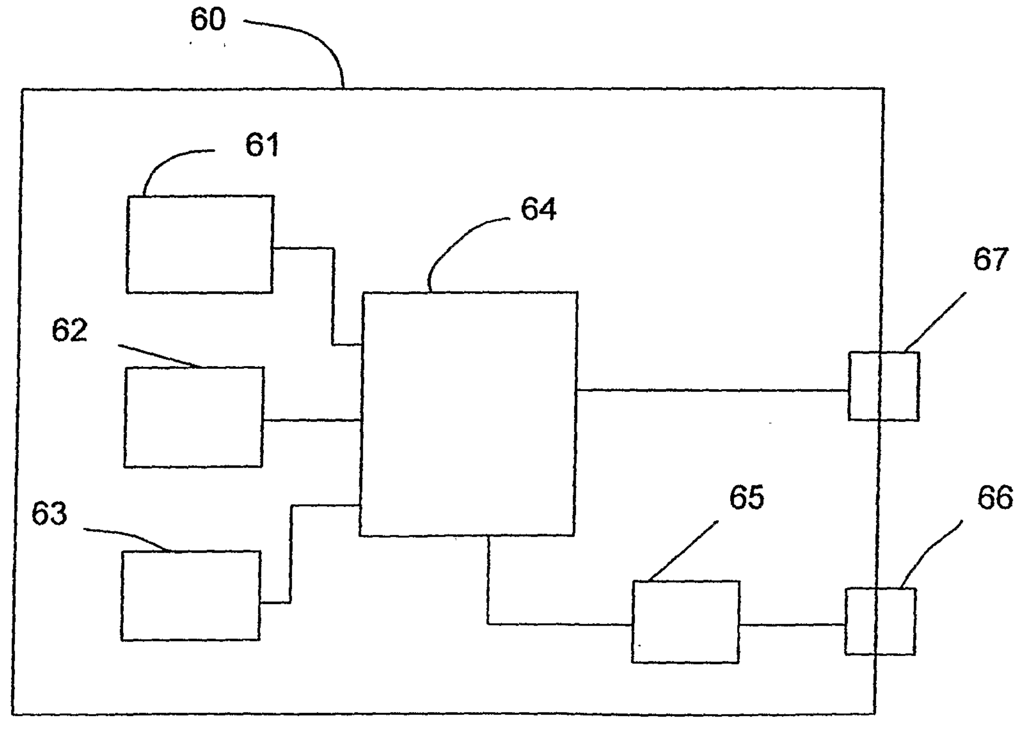


Figure 6

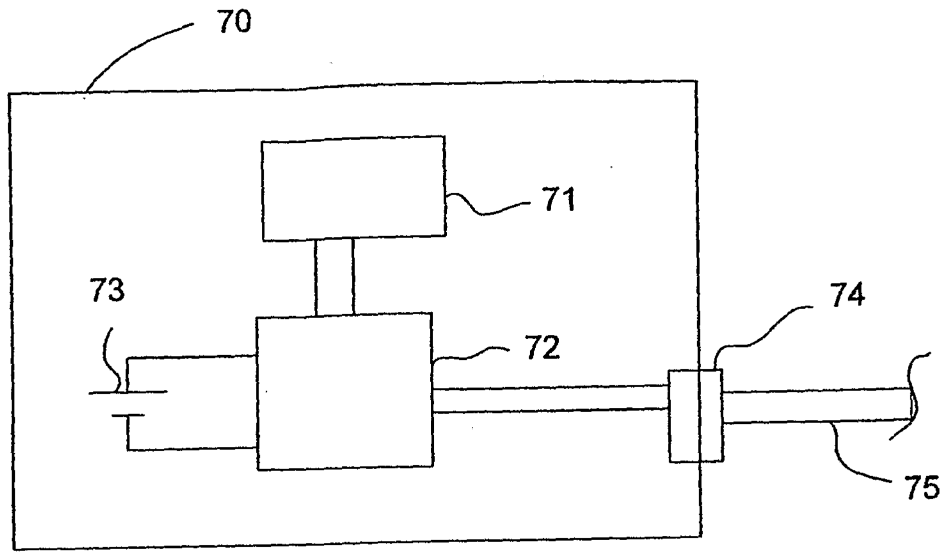


Figure 7

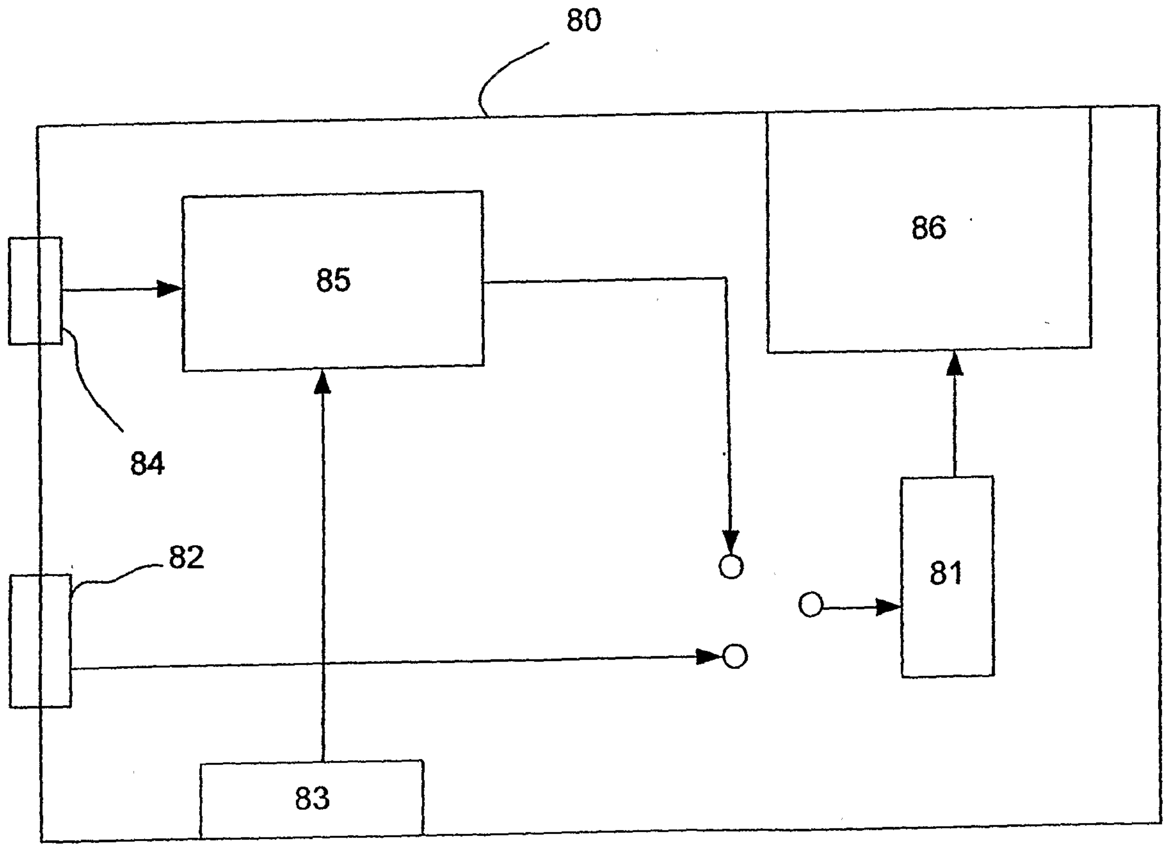


Figure 8

# INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/050066

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. H04B10/22

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>Y | JP 05 041729 A (FUJITSU GENERAL LTD) 19 February 1993 (1993-02-19) abstract; figures 1,2 | 1-7,9-13<br>8 |
| Y<br>A | GB 2 366 475 A (KHAN MOHAMMED SALEEM [GB]) 6 March 2002 (2002-03-06) the whole document | 8<br>1-7,9-13 |
| A | DE 197 32 974 A1 (BERNHARDT ULF DIPL ING [DE]) 4 February 1999 (1999-02-04) abstract; figures 1,4 | 1-13 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 22 April 2008 | 29/04/2008 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Shaalan, Mohamed |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2008/050066

| Patent document cited in search report | | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|---|
| JP 5041729 | A | 19-02-1993 | NONE | |
| GB 2366475 | A | 06-03-2002 | NONE | |
| DE 19732974 | A1 | 04-02-1999 | NONE | |