

INFRARED REPEATER

The present invention relates to an infrared repeater, and more specifically an infrared repeater which remains
5 operative in the presence of interference caused by compact fluorescent lights.

Current wireless remote control units for consumer electronic equipment, such as television receivers, video cassette recorders, and cable or satellite receiver boxes, operate by
10 transmitting an infrared (IR) light signal, representing a coded signal modulated on a modulating signal, from the remote control unit to the consumer electronic equipment. This modulated IR light signal is received by an IR receiver in the consumer electronic equipment, demodulated, decoded, and the appropriate
15 action taken. IR remote control units are line-of-sight devices, meaning that any consumer electronic equipment which is in a shadow with respect to the IR light generated by the remote control unit will not be able to receive the IR light signal and respond to the command. In addition, IR remote control units
20 have a limited operational range, which is sufficient for use within a room, but not sufficient for use between rooms.

Currently, however, consumer electronic equipment is being placed inside of pieces of furniture, such as home entertainment units, behind solid doors. For example, a television,
25 cable box, satellite receiver, etc., may be placed in a home entertainment unit in such a manner that, though the television receiver is visible to the viewer, the cable box, satellite receiver and VCR are placed behind solid doors. In addition, consumer electronic equipment is being distributed among different rooms
30 in a home. For example, a satellite receiver might be located next to one television receiver in a family room, but may also coupled to a second television receiver in a bedroom. The IR light

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generated by remote control units cannot penetrate through solid doors or pass from room to room, so the hidden or remotely located equipment may not be controlled.

To provide the capability of controlling consumer
5 electronic equipment within cabinets or in different rooms of a home, IR repeaters have been developed. An IR repeater includes an IR receiver section located where it can receive the coded modulated IR signal generated by the remote control unit. For example, it may be located on the outside of an entertainment
10 unit or in the room in which the remote control unit is being used. The IR receiver section is connected to an IR transmitter section located where the consumer electronic equipment which is to be controlled can receive its signal. For example, it is located inside of the entertainment unit or in the room in which the consumer
15 electronic equipment is located. The IR transmitter section includes an IR light emitter which is placed so that the emitted IR light impinges on the IR receiver in the consumer electronic equipment to be controlled. More specifically, the IR light emitter is usually placed directly adjacent to the IR receiver in the
20 consumer electronic equipment. The IR receiver section of the IR repeater detects the coded IR light signals produced by the remote control unit and transmits them to the IR transmitter section, usually via a wire. The IR transmitter section generates an IR light signal which is identical to the IR light signal received
25 by the IR receiver section. The consumer electronic equipment receives this IR light signal from the IR transmitter section, and performs the desired function.

Different manufacturers of consumer electronic equipment use different modulating frequencies for modulating
30 the coded control signal onto the IR light signal. In order for IR repeaters to work with the respective manufacturers' modulation frequencies, IR repeaters use an IR detector in the IR receiver section which has a relatively wideband frequency response characteristic. That is, it will detect modulated IR light signals for

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which the modulating frequency can vary over a relatively wide range of frequencies. For example, IR repeaters can generally detect IR light signals which are modulated at any modulating frequency from about 20 kilohertz (kHz) to 100 kHz. Any
5 modulated IR signal in this frequency range may be detected by the IR receiver, and when detected, an IR signal mimicking the received signal is generated at the IR transmitter.

Recently fluorescent lights having electronic ballast, termed compact fluorescent lights (CFLs), have been developed as
10 a replacement for incandescent lights. CFLs use less energy than incandescent lights, and have become popular for that reason. However, CFLs produce IR light which has characteristics similar to those of the coded modulated IR light signals produced by remote control units. That is, the electronic ballast in a CFL causes
15 the fluorescent tube to produce IR light signals which appear to be modulated by a modulating frequency in the range of 20 to 100 kHz, and specifically by a frequency of about 56 kHz. In addition, the IR light produced by CFLs has an intensity far greater than that produced by remote control units. Thus, the IR light
20 produced by a CFL completely overpowers the coded modulated IR light signal produced by a remote control unit. Because current IR repeaters mimic the IR signal received by its receiving section, any interference from nearby CFLs picked up by the IR repeater is also mimicked in the IR light signal produced by the IR
25 repeater. It has been found that, in the presence of CFLs, IR repeaters have seriously degraded performance or even become completely inoperative.

IR detectors have been developed which are resistant to interference caused by CFLs. These detectors can receive an IR
30 light signal representing a coded modulated control signal from a remote control unit in the presence of interfering IR light from a CFL and, in a known manner, cancel the interference from the CFL. The coded modulated IR light signal from the remote control

unit is then demodulated, and such an IR detector produces an electrical signal representing the coded control signal.

An IR repeater which can operate with remote control units from many manufacturers, and which can operate reliably in the presence of CFLs is desirable.

In accordance with an aspect of the invention, there is provided an infrared repeater, comprising receiving means for receiving an IR input signal comprising a modulated data signal with a first carrier frequency and providing an output signal;

transmitter means coupled to said receiving means and responsive to said output signal of said receiving means for providing an IR output signal including said data signal and having a second carrier frequency;

said receiving means demodulates said data signal to provide a detected data signal without a carrier;

said transmitter means comprises a fixed frequency oscillator providing a carrier signal with a frequency independent of that of said modulated data signal;

said oscillator carrier signal being modulated by said detected data signal and coupled to an IR transmitter for providing a repeated IR output signal having a carrier frequency independent of said given carrier frequency of said IR input signal; and wherein

said repeated IR signal includes substantially all of the modulation originally present on said IR input signal.

If a CFL resistant IR detector is used in the receiver section, the effect of CFLs can be minimized, and the operation of the receiver portion will not be seriously degraded by CFLs. The receiver section is tuned to respond to a modulating signal center frequency about in the middle of the range of frequencies used by the respective manufacturers, and the frequency of the modulating signal produced by the oscillator is also about in the middle of that range of frequencies. Because the frequency of the modulating signal in the IR signal produced by the transmitter section of the IR repeater is about in the middle of the range of frequencies used by the respective manufacturers, it may be detected by the IR receivers in the consumer electronic equipment of any such manufacturer. In addition, the transmitter modulating signal is a clean signal produced by an

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oscillator in the repeater, not mimicked from the receiver section. Thus, the signal produced by an IR repeater according to the present invention will produce a clean modulated IR light signal, free of CFL interference.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawing:

FIGURE 1 is a block diagram illustrating a remote control system including an IR repeater according to the present invention;

FIGURE 2 is a waveform diagram useful in understanding the operation of the present invention;

FIGURE 3 is a schematic diagram illustrating in more detail the IR repeater illustrated in FIGURE 1; and

FIGURE 4 is a schematic diagram illustrating an alternative embodiment for an IR detector illustrated in FIGURE 3.

In FIGURE 1, a remote control unit 10 provides coded control signals modulated on an IR light signal to an IR light detector 25 of an IR receiver section 20 of an IR repeater. In the IR repeater of FIGURE 1, the IR light detector 25 is illustrated as an IR phototransistor, although any IR light detecting device may be used. A control output terminal of the IR receiver section 20 is coupled to a control input terminal of a signal gate 30. A fixed frequency oscillator 40 has a signal output terminal coupled to a signal input terminal of the signal gate 30. A signal output terminal of the signal gate 30 is coupled to an input terminal of an IR transmitter section 50 of the IR repeater. The IR transmitter section 50 is coupled to an IR light emitter 55 which produces an IR light signal corresponding to the electrical signal received at the input terminal of the IR transmitter section 50. In the IR repeater of FIGURE 1, the IR light emitter is illustrated as an IR light emitting diode (LED), although any IR light emitting device may be used. This IR light emitter 55 is placed so that the IR light emitted impinges upon an IR light detector 65 of a piece of consumer electronic equipment 60. In FIGURE 1, the IR light detector 65 is illustrated as an IR phototransistor, although any IR light detecting device may be used. In addition, the consumer electronic equipment 60 is illustrated as a television receiver,

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although the IR repeater of FIGURE 1 will work with any consumer electronic equipment which can be remotely controlled by an IR remote control unit.

In operation, the remote control unit 10 produces a coded modulated IR light signal. In the illustrated embodiment, the coded signal (described in more detail below) is a pulse code modulated (PCM) signal representing a command for the television receiver 60. This signal is detected by the IR phototransistor 25, which generates an electrical signal representing the coded modulated signal, and supplies that signal to the IR receiver section 20. The IR receiver section 20 demodulates the electrical signal from the IR light sensor 25, and produces a bistate signal representing the pulses making up the PCM signal. This signal has a first state representing the presence of modulated IR light at the IR phototransistor 25, e.g. a logic '1' signal; and a second state representing the absence of modulated IR light at the IR phototransistor 25, e.g. a logic '0' signal. This signal is supplied to the control input terminal of the signal gate 30.

The fixed frequency oscillator 40 produces a modulating signal having a frequency of around 47 kHz at its output terminal. This frequency is selected to be close to the middle of the range of frequencies (from around 32 kHz to around 56 kHz) used by respective manufacturers to modulate their PCM signals on the IR light signal from their remote control units. This modulating signal is supplied to the data input terminal of the signal gate 30. The signal gate 30 operates as a controllable switch. When the signal from the IR receiver section 20 is a logic '1' signal (representing the presence of modulated IR light at the IR phototransistor 25), the signal gate 30 is conditioned to pass the modulating signal at its signal input terminal to its output terminal. When the signal from the IR receiver section 20 is a logic '0' signal (representing the absence of modulated IR light at

the IR phototransistor 25), the signal gate 30 is conditioned to block the modulating signal at its input terminal. The output signal from signal gate 30 is an electrical signal representing the received coded signal modulated on a 47 kHz modulating signal.

5 The signal from the signal gate 30 is supplied to the IR transmitting section 50. The IR transmitting section 50 conditions this signal to drive the IR LED 55 so that it produces an IR light signal corresponding to this modulated signal. The IR light signal produced by the IR LED 55, thus, is the pulse coded signal
10 received by the IR phototransistor 25, but modulated on a 47 kHz modulating signal. This coded modulated IR light signal impinges on the IR phototransistor 65 in the television receiver 65. The television receiver 60 responds in the normal manner to the received modulated coded IR light signal by executing the
15 command represented by that coded signal.

FIGURE 2 is a waveform diagram useful in understanding the operation of the present invention. The waveforms illustrated in FIGURE 2 represent the coded modulated signals as produced both by the remote control unit 10 (of FIGURE
20 1) and the IR LED 55 of the IR repeater. The differences between the signals produced by these respective sources will be described below. In FIGURE 2, a series of code pulses are illustrated. In FIGURE 2a, the pulses are arranged to form a pulse position coded signal. A series of clock pulses C1, C2, C3, ... are produced with
25 data pulses D1, D2, ... interspersed between them. The time position of the data pulses D1, D2 ... between the clock pulses C1, C2, C3, ... determines whether a logical '1' or '0' is being transmitted during the interval between successive clock pulses C1, C2, C3,

30 Referring to clock pulses C1 and C2 and data pulse D1, the data pulse D1 is closer in time to clock pulse C1 than to clock pulse C2. This represents a data bit having a logic '1' value. Referring now to clock pulses C2 and C3 and data pulse D2, the data pulse D2 is closer in time to clock pulse C3 than to clock pulse
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C2. This represents a data bit having a logic '0' value. Had the first data pulse been transmitted at the alternative time D1a, it would have represented a data bit having a logic '0' value, and had the second data pulse been transmitted at the alternative
5 time D2a, it would have represented a data bit having a logic '1' value. A control signal comprises a predetermined number of data bits.

FIGURE 2b illustrates in more detail the composition of clock pulse C2 illustrated in FIGURE 2a. Each pulse illustrated in
10 FIGURE 2a has a predetermined pulse width, and is composed of cycles of IR light pulses occurring at the modulating frequency. In FIGURE 2b, shaded areas represent the presence of IR light, and blank areas represent a lack of IR light. The envelope of the IR light pulses, repeating at the modulating frequency, defines the
15 clock and data pulses illustrated in FIGURE 2a. For the modulated coded pulses produced by the remote control unit 10 (of FIGURE 1), the modulating frequency is that used by the manufacturer of the remote control unit 10 (running from about 32 kHz to about 56 kHz.) For the modulated coded pulses produced by the IR LED
20 55 of the transmitting section 50 of the IR repeater, the modulating frequency is selected to be about 47 kHz.

Referring again to FIGURE 1, as described above, the IR light receiver section 20 is designed to detect and minimize the effects of spurious IR light emitted by CFLs. The IR light emitted
25 by CFLs consists of successive groups of IR light pulses having a frequency between about 20 and 100 kHz. The light pulses have envelopes defined by the AC power supplied to the CFL. Within each half cycle of the AC power the CFL produces a group of IR light pulses. The envelopes of the groups have a duty cycle of
30 around 50% and the groups occur at a frequency of about twice the AC power frequency. Specifically, it has been found that one type of CFL produces IR light pulses at around 56 kHz, with envelopes having a repetition frequency in the United States of 120 Hz and a duty cycle of 40%. The characteristics of these

pulses are sufficiently different from those of the pulses illustrated in FIGURE 2b that the IR receiver section 20 is able to detect IR light pulses having these characteristics and cancel or minimize their effect.

5 As described above, the coded modulated IR light signal produced by the IR LED 55 of the IR transmitter section 50 may have a modulating frequency slightly different than that expected by the television receiver 60. However in an IR repeater application, this is not a problem. A remote control unit 10
10 operates from battery power and, thus, produces IR light at a relatively low power level. In addition, a remote control unit is generally operated at a relatively large distance from the television receiver, e.g. on the order of several feet away. The IR light receiver in the television receiver is sensitive enough to
15 detect the IR light signals produced under these circumstances. But IR repeaters are generally coupled directly to the home AC power source and, thus, can produce IR light at a relatively high power level. Also, as described above, the IR LED 55 of the IR transmitter section 50 of the IR repeater is generally physically
20 placed in close proximity to the IR phototransistor 65 of the television receiver. The relatively high power level of the IR light signal produced by the IR LED 55, and close proximity of the IR LED 55 and the IR phototransistor 65, more than overcomes the slight mistuning between the 47 kHz modulating frequency
25 produced by the IR repeater and the modulating signal frequency expected by the television receiver 60.

As described above, the transmitter section of prior art IR repeaters produces an IR light signal which mimics that received by the receiver section. Thus, if the received IR light
30 signal is corrupted with IR light from a CFL, the transmitted IR light signal will be similarly corrupted. The performance of such IR repeaters is greatly diminished in the presence of CFLs, and some are rendered completely inoperative. An IR repeater as illustrated in FIGURE 1, however, uses a receiver section which is

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resistant to CFL interference. The output signal from such a receiver section (representing the demodulated coded signal) is used to modulate a clean oscillator signal from an oscillator within the IR repeater. This clean, newly generated, modulated signal
5 controls the IR light emitter in the transmitter section. The IR light generated by the IR emitter in response to such a signal does not include any CFL interference, and its operation is not degraded in the presence of CFLs.

FIGURE 3 is a schematic diagram illustrating in more
10 detail the IR repeater illustrated in FIGURE 1. In FIGURE 3, a source of operating power (not shown) produces a 5 volt power signal. A resistor R1 is coupled between the source of operating power and a collector electrode of an NPN transistor Q1. The signal electrodes of an IR detector 202 are coupled between an
15 emitter electrode of the transistor Q1 and a source of a reference potential (ground). The IR detector 202 also receives operating power by being coupled to the source of operating power. The IR detector 202 is tuned to a modulating signal center frequency of 45 kHz and is a model GP1U78QG IR detector manufactured by
20 Sharp Electronics Corporation. A resistor R2 is coupled between the source of operating power and a base electrode of the transistor Q1. A resistor R3 is coupled between the source of operating power and a collector electrode of an NPN transistor Q2. An emitter electrode of the transistor Q2 is coupled to ground. A
25 resistor R4 is coupled between the source of operating power and a base electrode of the transistor Q2. A capacitor C1 is coupled between the base electrode of the transistor Q2 and the collector electrode of the transistor Q1, and a capacitor C2 is coupled between the base electrode of the transistor Q1 and the collector
30 electrode of the transistor Q2.

A resistor R6 is coupled between the source of operating power and a collector electrode of an NPN transistor Q3. A resistor R7 is coupled between an emitter electrode of the transistor Q3 and ground. A resistor R5 is coupled between the
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collector electrode of the transistor Q2 and a base electrode of the transistor Q3. The serial connection of a resistor R8 and an IR LED 55 is coupled between the source of operating power and a collector electrode of an NPN transistor Q4. An emitter electrode of the transistor Q4 is coupled to ground. The emitter electrode of the transistor Q3 is coupled to a base electrode of the transistor Q4. The IR LED 55 may be connected to the resistor R8 and the transistor Q4 via a long length of wire, e.g. meant to run from one room to another. The transistors Q1, Q2, Q3 and Q4 are all model MPS-A20 NPN transistors manufactured by Motorola Corporation. Table I contains preferred component values for the circuit illustrated in FIGURE 3.

In operation, the IR detector 202 detects the presence of IR light modulated at the predetermined modulating signal center frequency (e.g. 45 kHz) while minimizing the effect of spurious IR light from CFLs, as described above. When modulated IR light is detected, the IR detector 202 is conditioned to conduct current between its two signal electrodes, and when no modulated IR light is detected, the IR detector 202 is conditioned to become nonconductive.

Component Values	
R1,R3	1 k Ω
R2,R4	100 k Ω
R5	10 k Ω
R6	1 k Ω
R7	10 k Ω
R8	100 Ω
C1,C2	180 pf
IR DET	GP1U78QG
Q1,Q2,Q3,Q4	MPS-A20

TABLE I

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When the IR detector 202 is nonconductive (indicating no modulated IR light is being detected), transistor Q1 is turned off, and both capacitors act as open circuits. The base electrode of the transistor Q2 is pulled high through resistor R4, and the
5 transistor Q2 is turned on, pulling the voltage at its collector electrode to ground potential. The base electrode of transistor Q3 is pulled down through resistor R5, turning transistor Q3 off. The base electrode of transistor Q4 is pulled down through resistor R7 turning transistor Q4 off, and preventing current from flowing
10 through the IR LED 55. In short, when no modulated IR light is detected by IR detector 202, no IR light is emitted by IR LED 55.

When the IR detector 202 is conductive (indicating that modulated IR light is being detected), the emitter electrode of the transistor Q1 is coupled to ground. The combination of the
15 transistors Q1 and Q2, the resistors R1, R2, R3 and R4, the capacitors C1 and C2 and the IR detector 202 operates in a known manner as a multivibrator oscillator (40 in FIGURE 1) adjusted to oscillate and generate a square wave at about 47 kHz. The signal at the collector electrode of the transistor Q2, thus, is a 47 kHz
20 square wave signal produced during periods when modulated IR light is detected by the IR detector 202. The IR detector 202 operates as a switch turning the multivibrator on and off. The combination of the transistors Q3 and Q4, the resistors R5, R6, R7 and R8, and the IR LED 55 forms the transmitting section (50) and
25 operates in a known manner as a two stage emitter-follower amplifier, responsive to the oscillator 40 output, to drive the IR LED 55 on and off at a frequency of 47 kHz during periods when modulated IR light is detected by the IR detector 202. Thus, the IR LED 55 generates a coded IR light signal modulated at a
30 frequency of 47 kHz. The IR detector 202 acts as the signal gate 30, controlling the transmission of the modulating signal from the oscillator 40 to the transmitting section 50.

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FIGURE 4 is a schematic diagram illustrating an alternative embodiment for an IR detector 202 illustrated in FIGURE 3. The IR detector 202 in the IR repeater illustrated in FIGURE 3 is a single IR detector fabricated and tuned to have a modulating signal center frequency response of about 45 kHz.

In FIGURE 4 the emitter electrode of the transistor Q1 is coupled to ground through the parallel connection of a first IR detector 204 and a second IR detector 206. The first IR detector 204 is tuned to a modulating signal center frequency of 38 kHz, and is a model TFMS1380 IR detector manufactured by TEMEC Telefunken Microelectronic GmbH. The second IR detector 206 is tuned to a modulating signal center frequency of 56 kHz, and is a model TFMS1560 IR detector, also manufactured by TEMEC.

An IR repeater as described above provides reliable operation in the presence of CFLs and operates with a variety of manufacturers' equipment.

CLAIMS:

1. An infrared repeater, comprising:
receiving means (20) for receiving an IR input signal comprising a modulated data signal with a first carrier frequency and providing an output signal;
transmitter means (40,30,50) coupled to said receiving means and responsive to said output signal of said receiving means for providing an IR output signal including said data signal and having a second carrier frequency;
said receiving means (20,25) demodulates said data signal to provide a detected data signal without a carrier;
said transmitter means comprises a fixed frequency oscillator (40) providing a carrier signal with a frequency independent of that of said modulated data signal;
said oscillator carrier signal being modulated (30) by said detected data signal and coupled to an IR transmitter (50,55) for providing a repeated IR output signal having a carrier frequency independent of said given carrier frequency of said IR input signal; and wherein
said repeated IR signal includes substantially all of the modulation originally present on said IR input signal.
2. An infrared repeater as recited in Claim 1 wherein said given carrier frequency of said IR input signal lies within a range of frequencies; and said carrier signal of said fixed frequency oscillator (40) has a frequency substantially in the middle of said range.
3. An infrared repeater as recited in Claim 1 wherein said given carrier frequency of said IR input signal lies within a range of frequencies having a lower end frequency and an upper end frequency ;
said receiving means comprises a first detector (204) tuned to a frequency substantially near said lower frequency and a second detector (206) tuned to a frequency substantially near said upper end frequency; and
said carrier signal of said fixed frequency oscillator (40) has a frequency substantially midway between said lower and upper frequencies of said IR input signal.