



AU9230108

(12) PATENT ABRIDGMENT (11) Document No. AU-B-30108/92
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 663541

(54) Title
COMBINED GROUND FAULT INTERRUPTOR CIRCUIT AND REMOTE CONTROL ON/OFF DEVICE

International Patent Classification(s)
(51)⁵ H02J 013/00 G08C 017/00 H02H 003/16

(21) Application No. : 30108/92 (22) Application Date : 11.12.92

(30) Priority Data

(31) Number	(32) Date	(33) Country
823678	21.01.92	US UNITED STATES OF AMERICA
918249	23.07.92	US UNITED STATES OF AMERICA

(43) Publication Date : 22.07.93

(44) Publication Date of Accepted Application : 12.10.95

(71) Applicant(s)
FELCHAR MANUFACTURING CORPORATION

(72) Inventor(s)
MARK BAER; JAMES M ROBITAILLE

(74) Attorney or Agent
GRIFFITH HACK & CO. , GPO Box 4164, SYDNEY NSW 2001

(56) Prior Art Documents
US 4959647
US 4057805
GB 2198614

(57) Claim

1. Apparatus for remotely controlling electrical equipment including an electrical load and power lines for connecting the load to a power supply, said apparatus comprising:

- a) a first switch for connection in the power lines and operable between open and closed positions to control power to the load;
- b) a second switch connected to control operation of said first switch;
- c) a ground fault interrupter circuit connected to control operation of said second switch;
- d) a third switch connected to control operation of said first switch; and
- e) radiation signal responsive means for controlling said third switch.

- 1 -

663541

P/00/011
Regulation 3.2

AUSTRALIA

Patents Act 1990

ORIGINAL
COMPLETE SPECIFICATION
STANDARD PATENT

Invention Title: COMBINED GROUND FAULT INTERRUPTOR
CIRCUIT AND REMOTE CONTROL ON/OFF
DEVICE

The following statement is a full description of this invention, including
the best method of performing it known to us:

GH&CO REF: P22558-A:CLC:RK

-1A-

COMBINED GROUND FAULT INTERRUPTER
CIRCUIT AND REMOTE CONTROL ON/OFF DEVICE

5

BACKGROUND OF THE INVENTION

10 The present invention relates to apparatus for remotely controlling electrical equipment and, more particularly, to a combined ground fault interrupter circuit and remote control on/off device.

15 Remote control on/off devices for electrically powered apparatus are known. Generally, such devices comprise two units: a transmitter located remotely and a receiving unit located in the apparatus which it is designed to control. One disadvantage of such an arrangement is the requirement of providing a receiver in the apparatus being remotely controlled. This requires that the apparatus be designed with remote control as one of its objects. The corollary to this is that apparatus which has not been so designed cannot be remotely controlled. Additionally, adding a receiver to the apparatus increases its cost. For some apparatus, such as household appliances, this increase in cost could make the appliance prohibitively costly.

20



SUMMARY OF THE INVENTION

It is preferably an advantage of at least a preferred embodiment of the present invention to provide apparatus for remotely controlling electrical equipment which does not require any modification of the equipment and which enables equipment which has not been designed for remote control to be so controlled.

The present invention preferably accomplishes this by combining an on/off device responsive to electromagnetic radiation with a ground fault interrupter circuit.

Ground fault interrupter circuits interrupt the application of electric power to a load in response to a ground fault or similar type of circuit fault. Typically, a ground fault interrupter circuit includes a circuit breaker and a fault sensing circuit. When the fault sensing circuit senses an imbalance exceeding a predetermined magnitude between the currents in the power lines connected to the load, a fault signal is generated to open the circuit breaker and thereby disconnect power from the load.

The present invention provides an apparatus for remotely controlling electrical equipment including an electrical load and power lines for connecting the load to a power supply, said apparatus comprising:

- a) a first switch for connection in the power lines and operable between open and closed positions to control power to the load;
- b) a second switch connected to control operation of said first switch;
- c) a ground fault interrupter circuit connected to control operation of said second switch;
- d) a third switch connected to control operation of said first switch; and
- e) radiation signal responsive means for controlling said third switch.

Preferably, a remote on/off device includes a



radio frequency transmitter for generating a remote on/off signal and a receiver is provided responsive to the signal received from the transmitter for applying a signal to the circuit breaker of the ground fault interrupter circuit to close or open the circuit breaker.

In a preferred embodiment, the invention is employed with a ground fault interrupter of the type which is housed in the plug of the power cord. This has the advantage of providing remote on/off control to electrical apparatus without the necessity of any modifications to the apparatus itself.

The present invention further provides an apparatus for remotely controlling electrical equipment, which comprises:

15 a ground fault interrupter circuit having first means selectively operable for connecting and disconnecting a source of power to the electrical equipment; and

20 second means responsive to electromagnetic radiation for selectively operating said first means.

The present invention yet further provides an apparatus for remotely controlling electrical equipment, which comprises:

25 a ground fault interrupter circuit having means selectively operable for connecting and disconnecting a source of power to the electrical equipment;

a transmitter for generating electromagnetic radiation when it is desired to operate the connecting and disconnecting means; and

30 means responsive to electromagnetic radiation for selectively operating the connecting and disconnecting means.

BRIEF DESCRIPTION OF THE DRAWINGS

35 Fig. 1 is a block diagram of apparatus comprising a remote on/off device and a ground fault interrupter circuit in accordance with certain principles of the present invention;

Fig. 2 is a schematic of a transmitter circuit



forming part of the remote on/off device;

Figs. 3A and 3B combined, with Fig. 3B to the right of Fig. 3A, illustrate schematically a receiver forming part of the remote on/off device and the
5 interconnection of the receiver and the ground fault interrupter circuit;

Fig. 4 is a schematic of an operational amplifier unit forming part of the receiver of Fig. 3;

Fig. 5 is a schematic of a flip-flop forming
10 part of the receiver of Fig. 3; and

Fig. 6 is a schematic of a receiver in accordance with a preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and, in particular
15 to Figure 1, there is shown a ground fault interrupter circuit 10 selectively controlled by a remote

control on/off device 11 which includes a transmitter 12 and a receiver 13.

Typically, the ground fault interrupter circuit 10 includes one or more differential transformers 14 to monitor the current through the hot and neutral lines 16 and 17, respectively, connecting a source of AC power 18 to a load 19. Whenever an imbalance exists between the currents of the hot and neutral lines 16 and 17, the differential transformers generate a fault signal. The fault signal is typically monitored by a fault sensing circuit 21 which controls the operation of a circuit breaker 22 which, in normal operation, connects the hot and neutral lines 16 and 17 to the load 19. A typical ground fault circuit interrupter also includes an AC/DC power supply 23, a reset switch 24, and a test switch 26. In operation, when a fault, such as an imbalance between the currents in the hot and neutral lines 16 and 17 is sensed, the circuit breaker 22 is opened to disconnect the lines 16 and 17 from the load 19. After correction of the fault, the reset switch 24 is closed to apply a reset signal to the fault sensing circuit 21 to reclose the circuit breaker and reestablish connection between the source 18 and the load 19. The test circuit functions to create an imbalance between the hot and neutral lines 16 and 17 which, if the ground fault interrupter circuit is functioning normally, will create an imbalance in the differential transformers to cause the fault sensing circuit 21 to open the circuit breaker 22. While many ground fault interrupter circuits are suitable for use in practicing the present invention, a

preferred ground fault interrupter circuit is illustrated in U.S. Patent No. 5,177,657, issued January 5, 1993 and entitled "Ground Fault Interrupter Circuit with Electronic Latch," the disclosure of which is
5 incorporated by reference herein.

Referring now to Fig. 2, the transmitter 12 includes a low frequency oscillator 27 coupled to an RF oscillator/modulator 28, an antenna 29 coupled to the output of the RF oscillator/modulator 28, a power
10 source in the form of a battery 31 and an on/off switch 32.

The low frequency oscillator 27 generates a modulating signal and includes a pair of inverters 33 and 34 interconnected with resistors 36, 37 and 38 and
15 a capacitor 39 to form a low frequency oscillator, which typically may oscillate at a frequency of 1 kilohertz.

The RF oscillator modulator 28 functions to generate an RF carrier frequency and includes a transistor 41 and a tank circuit 42 interconnected between
20 the base 43 and the collector 44 of the transistor along with a pair of capacitors 46 and 47. The antenna 29 is connected to the collector 44 of the transistor 41. The emitter 48 of the transistor 41 is connected
25 through a resistor 49 to ground and the base 43 of the transistor 41 is connected through a resistor 51 to the output of the low frequency oscillator 27. DC power is supplied to the RF oscillator/modulator through a resistor 52 and a choke 53. A capacitor 54 is connect-
30 ed from one end of the choke 53 to ground to bypass unwanted frequencies.



The components which make up the RF oscillator/modulator 28 are selected such that the RF oscillator/modulator operates close to the low end of the AM frequency band. This enables smaller size components to be used so that the overall size of the transmitter 12 may be kept small. Typically, the frequency is in the range between 300 kilohertz to approximately 600 kilohertz. A longer wave length is used for a greater range transmission and a greater penetration of the transmitter output through objects that may lie between the transmitter 12 and the receiver 13.

When power is applied to the low frequency oscillator 27 and the RF oscillator/modulator 28 circuit by closure of the switch 32, both the low frequency oscillator and the RF modulator oscillator begin oscillating at their respective frequencies. The output of the low frequency oscillator 27, which is applied to the base 43 of the transistor 41 through the resistor 51, modulates the amplitude of the output at the collector 44 of the transistor 41 at the frequency of the low frequency oscillator. This modulated signal is then outputted from the transmitter 12 via the antenna 29. Preferably, since only a momentary burst from the transmitter 12 is necessary, the switch 32 is of the push-button type.

Referring now to Figs. 3A and 3B, the receiver 13 includes an antenna 56 connected to an input RF amplifier 57. The input RF amplifier 57 includes a transistor 58 and the antenna 56 is coupled to the base 59 of the transistor 58 through a capacitor 61 and to

ground or common through a capacitor 62. Also connected to the base 59 of the transistor are resistors 63 and 64. An RC circuit comprising a resistor 66 and a capacitor 67 are connected between ground and the emitter 68 of the transistor 58. The collector 69 of the transistor 58 is connected through an output resistor 71 and a resistor 72 to a DC power lead. Capacitors 74 and 76 are connected from the junction of the resistors 71 and 72 to the emitter 68 of the transistor 58 and to ground, respectively.

The output of amplifier 57, which appears across the resistor 71, is inductively coupled from the primary winding 77 of a tank circuit 78 to the secondary winding 79 which forms the input to a mixer/oscillator 81. The mixer/oscillator includes a transistor 82 with one end 83 of the secondary 79 of the tank circuit 78 connected to the collector 84 of the transistor 82. A choke 86 and a resistor 87 are connected to the emitter 88 of the transistor 82 and a resistor 89 is connected to the base 91 thereof to adjust the DC biasing of the transistor 82. A capacitor 92 is connected from the end 93 of the secondary 79 to the junction of the choke 86 and the resistor 87 and a capacitor 94 is connected from the junction to the base 91 of the transistor 82. A resistor 96 is connected from the end 93 of the secondary 79 to the base 91 of the transistor 82, while a capacitor 98 is connected across the secondary winding 79.

The values of the components of the mixer oscillator 81 are selected such that the oscillator oscillates at a local RF frequency which is the same as

the RF frequency of the oscillator/modulator 27 and 28 of the transmitter 12. The mixer/oscillator 81 combines the locally generated RF frequency with the RF modulated signal inductively coupled from the output of the RF amplifier 57 such that the two RF signals essentially cancel one another, leaving essentially only the modulating frequency, i.e., the output of the low frequency oscillator 27 of the transmitter 12.

The output of the mixer/oscillator 81 is then applied to the input 102 of a square-wave generator 103 through a resistor 101. A capacitor 104 is connected to the resistor 101 and functions to remove any remaining RF components of the output signal of the mixer/oscillator 81.

The square wave generator 103 includes a dual input operational amplifier unit 106, such as a Philips ECG 358, a functional block diagram of which is shown in Fig. 4. As seen in Fig. 4, the unit 106 includes a pair of operational amplifiers 107 and 108. The operational amplifier 107 includes an inverting input at pin 2, a non-inverting input at pin 3 and an output at pin 1. The operational amplifier 108 includes an inverting input at pin 6, a non-inverting input at pin 5 and an output at pin 7. Positive DC power is applied to pin 8 and negative DC power is applied to pin 4.

Turning back to Figs. 3A and 3B, and particularly to Fig. 3A, a resistor 109 is connected from the input 102 to the non-inverting input 5 of the operational amplifier 108 and a resistor 111 is connected from the input 102 to the inverting input pin 6 of the operational amplifier 108. A capacitor 112 is connect-

ed from the input pin 5 to ground. The output pin 7 of the operational amplifier 108 is connected to the non-inverting input pin 3 of the operational amplifier 107. A resistor 113 is connected between the inverting and non-inverting input pins 2 and 3, respectively, of the operational amplifier 107, while a capacitor 114 and a resistor 116 are connected from the input pins 2 and 3, respectively, to ground. A resistor 117 is connected between the inverting input pin 6 of the operational amplifier 108 and the non-inverting input 3 of the operational amplifier 107. A positive DC voltage is applied to the pin 8 and the pin 4 is connected to the ground. The gain of the operational amplifier unit 106 (i.e., the tandemly connected operational amplifiers 107 and 108) is set by the values of the resistors 109 and 117. A zener diode 118 and resistors 119 and 121 set the midpoint of operation of the operational amplifier unit 106.

The square wave output at pin 1 of the operational amplifier unit 106 is applied to a wave shaping circuit comprising a diode 122, a capacitor 123, and a resistor 124 which shapes the output of the operational amplifier into a trigger pulse for actuating a flip-flop 126. More specifically, the square wave output of the operational amplifier unit 106, after rectification by the diode 122, charges the capacitor 123. This provides a single trigger pulse for each train of square waves.

The flip-flop 126 is a D flip-flop and may be one of the dual flip-flops located on an integrated circuit, such as the National Semiconductor CD4013.

Referring to Fig. 5, which is a functional block diagram of the CD4013 integrated circuit, the flip-flop 126 has a Q output at pin 1, a Q output at pin 2, a clock input at pin 3, a reset input at pin 4, a data input at pin 5, a set input at pin 6 and positive and negative power inputs at pins 14 and 7, respectively. Referring back to Figs. 3A and 38, and particularly to Fig. 3A, the flip-flop 126 is arranged such that the leading edge of each trigger pulse, which is applied to pin 3 (the clock input), causes the outputs of the flip-flop 126 to change state. The Q output of the flip-flop 126 at pin 1 is applied through a resistor 127 to the base 128 of an output transistor 129 connected in a common emitter configuration. The collector 131 of the output transistor 129 is connected to the ground fault interrupter circuit 10 in parallel with the reset switch 24, and like the reset switch 24, functions to control operation of the circuit breaker 22.

To better understand how this is accomplished, it is necessary to go into the structure and operation of the ground fault interrupter circuit 10 in somewhat more detail. The circuit breaker 22 is under the control of a relay 132 which, in turn, is connected to the collector 133 of a transistor 134. The transistor 134 is normally biased to conduction by current flow through resistors 151 and 152, and the relay 132 is therefore normally closed by conduction of the transistor 133. The transistor 134 is controlled by an electronic latch circuit which includes an SCR 136 which is normally off or nonconducting. When a fault

is detected, a signal is applied to the gate 137 of the SCR 136 to turn the SCR 136 on. When the SCR 136 turns on, it shunts the base-emitter and base current is removed from the transistor 134, turning it off. This, in turn, de-energizes the relay 132 to open the circuit breaker 22. The voltage at this time across the SCR 136 is sufficient to keep the SCR on (i.e., latched) even after voltage is removed from the gate 137. The reset switch 24 is connected across the SCR 136 and functions to de-latch the SCR 136 by momentarily shorting it out, thereby removing current from the anode 138 of the SCR 136 to turn the SCR off. When the reset switch 24 is released, the SCR 136 will not turn on again unless a signal indicative of another fault is reapplied to the gate 137. Accordingly, when the reset switch 24 is released, base current returns to the transistor 134, thereby returning current flow to the relay 132 and again closing the circuit breaker 22.

The transistor 129 is connected in parallel with the SCR 136 and the reset switch 24, and the function of the transistor 129 is essentially identical to that of the reset switch 24. When the output transistor 129 is turned on, the SCR is shorted, removing base current from the transistor 134 to open the circuit breaker 22. When the output transistor 129 is turned off, e.g. by switching the output of the flip-flop 126 to its low state, ground is removed from the SCR 136 and base current is re-applied to the transistor 134, thereby turning on the transistor 134 and reenergizing the relay 132 to close the circuit breaker 22.

The following is a chart outlining the different modes of operation:

	<u>Normal Operation</u>	<u>Fault</u>	<u>Reset</u>	<u>First Remote Control Pulse</u>	<u>Second Remote Control Pulse</u>
5	Reset switch 24 open	Reset switch 24 open	Reset switch 24 closed	Reset switch 24 open	Reset switch 24 open
10	SCR 136 off	SCR 136 on	SCR 136 off	SCR 136 off	SCR 136 off
	trans. 134 on	trans. 134 off	trans. 134 off	trans. 134 off	trans. 134 on
15	relay 132 conducts	relay 132 non conduct	relay 132 non conduct	relay 132 non conduct	relay 132 conducting
	breaker 22 closed	breaker 22 open	breaker 22 open	breaker 22 open	breaker 22 closed
20	trans. 129 off	trans. 129 off	trans. 129 off	trans. 129 on	trans. 129 off

Although a separate power supply may be employed, power for the receiver is preferably obtained from the ground fault interrupter circuit 10. More specifically, the output of a full wave bridge rectifier 135 forming part of the ground fault interrupter circuit 10 is connected through a resistor 141 to the input of a voltage regulator 142, such as a Philips ECG 961. Capacitors 143, 149 and 146 are provided to filter undesirable AC components and a zener diode 147 is connected to the input of the voltage regulator 142 to limit the input voltage. The output of the regulator 142 is then applied to the power lead 73.

The receiver 13 may form an integral part of and be mounted in the same housing as the ground fault interrupter circuit 10 or, as shown be separate therefrom, in which case the receiver 13 is interconnected with the ground fault interrupter circuit by an auxiliary cable 148. Additionally, while the ground fault interrupter circuit 10 may be separately housed, it is preferably incorporated in the power plug of an electrical power cord (not shown).

The operation of the remote control on/off device 11 is described as follows in connection with remotely controlling the load 19. It is assumed that the ground fault interrupter circuit 10 and the receiver 13 are interconnected by the auxiliary cable 148, that power is applied to the ground fault interrupter circuit 10 and that the circuit breaker 22 is open, i.e., the SCR 136 is on and the transistor 134 is off.

To remotely turn on the load 19, the switch 32 in the transmitter 12 is depressed twice. The first depression causes an RF modulated signal to be sent from the transmitter 12 to the receiver 13. This then causes a square wave signal to be applied to the wave shaping circuit comprising diode 122 and capacitor 123 to generate a single trigger pulse. The trigger pulse causes the output Q at pin 1 of the flip-flop 126 to change from its low state to its high state, turning on the output transistor 129. Turning on the transistor 129 shorts the SCR 136, causing it to turn off. When the switch 32 is released, the RF signal ceases as does the output square wave from the operational amplifier. This enables the capacitor 123 to discharge through the

resistor 124. It should be noted that release of the switch 32 has no effect on the flip-flop 126 since the flip-flop 126 only triggers on the leading edge of a trigger pulse. Accordingly, the flip-flop 126 remains in its high state even after the switch 32 is released. When the switch 32 is subsequently depressed, an RF signal is again generated by the transmitter 12 and converted by the receiver 13 into a square wave signal which is then shaped into a trigger pulse. The leading edge of this pulse triggers the flip-flop 126 and causes the Q output thereof to change from a high state to a low state. This turns off the output transistor 129, removing ground from the base of the transistor 134 and allowing base drive current to be restored. The transistor 134 thus turns on, thereby energizing the relay 132 to close the circuit breaker 22 and connect the source 18 to the load 19.

Thereafter, when it is desired to turn the load 19 off, the switch 32 is again depressed, thereby generating another trigger pulse and changing the state of the flip-flop 126 to turn on the transistor 129 to remove base drive from the transistor 134. The transistor 134 thereby turns off, de-energizing the relay 132 and opening the circuit breaker 22.

Fig. 6 shows an alternative and preferred embodiment of the receiver 13. Bursts of pulses from an RF transmitter, such as the transmitter shown in Fig. 2, are received by an antenna and amplified by an RF amplifier transistor 162. The carrier frequency may be approximately 600 KHz and the modulating frequency may be approximately 1 KHz. The amplified pulse bursts

are passed to a tuned circuit 163 and to an oscillator/mixer transistor 164 which operates at and removes the carrier frequency. The resulting low frequency modulating signal is fed to the input of operational amplifier (op-amp) 166. Capacitor 167 removes any remaining RF carrier frequency and diode 168 sets the zero level for the signal applied to op-amp 166. The modulating signal is amplified by amplifier 166 and then applied to diode 169, capacitor 171 and resistor 172. The signal is rectified by the diode 169 and filtered by the capacitor 171, thereby forming a positive DC voltage on an output lead 173 in response to a burst of pulses received from the transmitter 12. When the pulse burst ceases, the resistor 172 forms a discharge path for the capacitor 171, thereby setting up the circuit for the next pulse burst.

It will be readily apparent from a comparison of Fig. 6 with Figs. 3A and 3B that the construction and operation of the portion of the receiver shown in Fig. 6 and described thus far is identical with that of the receiver shown in Figs. 3A and 3B. Consequently, a detailed identification of the circuit components and their operation would be unduly repetitious and unnecessary.

The output lead 173 is connected to the base 175 of a transistor 176, the emitter of which is connected to a common or ground line 177. The collector of the transistor 176 is connected to the emitter of a transistor 178 (which corresponds to the transistor 134 in Fig. 3A) of the ground fault interrupter circuit 10. A relay coil 179 is connected to the collector of the

transistor 178, the emitter-collector circuits of the two transistors 176 and 178 thus being connected in series with the relay coil 179 between a DC power supply 181 and the common line 177.

5 The transistor 178 is normally biased on by current flow through three resistors 182, 183 and 184 which are connected in series between the DC supply 181 and the base of the transistor 178. An SCR 186 is
10 connected between the common line 177 and the juncture of resistors 183 and 184, and when the SCR 186 is triggered on, it removes base current from the transistor 178. This action stops the current flow through the transistor 178 and the relay coil 179 and opens the circuit breaker. As described in U.S. Patent No.
15 5,177,657, a pulse in response to detection of a ground fault appears on a pin 187 of a controller, which triggers on the SCR 186. A reset switch (not illustrated in Fig. 6) is connected in parallel with the SCR 186.

20 Since the two transistors 176 and 178 are connected in series with the relay coil 179 between the DC supply 181 and common 177, the coil 179 will be energized only when both transistors are biased on. As a consequence, line power will be supplied to the load
25 19 only in the absence of a fault and while the transmitter is activated to radiate an electromagnetic signal which is picked up by the receiver 13 of Fig. 6. Either a ground fault or deactivation of the transmitter will stop current flow through the relay coil 179
30 and open the circuit breaker.



The receiver shown in Fig. 6 may be advantageously used, as an example, in a pressure washer including a hand-held nozzle or wand having a control trigger. In this example, the load 19 comprises an

5 electric motor which powers the pump of the washer. The transmitter "on" switch would be closed by squeezing the trigger, causing the transistor 176 to turn on and current to flow through relay coil 179. Thus the motor-pump would be under the control of the trigger
10 which operates the transmitter. The receiver shown in Figs. 3A and 3B on the other hand is better suited for a situation wherein a load is to be turned on by pressing and releasing the transmitter switch and later turned off by pressing and releasing the transmitter
15 switch a second time.

In the embodiment of the invention shown in Fig. 6, a three conductor cable connects the receiver to the ground fault interrupter. As a specific example, the output of the bridge rectifier 181 produces
20 approximately 100 VDC on line 191 which is reduced to approximately 27 VDC by a resistor 192 and a diode 193. A regulator 1C 194 produces approximately 8 VDC which powers the receiver components. A line 196 forms a ground or common return, and a line 197 connects the
25 transistors 176 and 178.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It
30 is preferred, therefore, that the present invention be

limited not by the specific disclosure herein, but only
by the appended claims.

2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217
2218
2219
2220
2221
2222
2223
2224
2225
2226
2227
2228
2229
2230
2

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Apparatus for remotely controlling electrical equipment including an electrical load and power lines for connecting the load to a power supply, said apparatus comprising:

- a) a first switch for connection in the power lines and operable between open and closed positions to control power to the load;
- b) a second switch connected to control operation of said first switch;
- c) a ground fault interrupter circuit connected to control operation of said second switch;
- d) a third switch connected to control operation of said first switch; and
- e) radiation signal responsive means for controlling said third switch.

2. Apparatus in accordance with Claim 1, and further including radiation signal generator means remote from said signal responsive means for generating a radiation signal.

3. Apparatus in accordance with Claim 1, wherein said radiation signal comprises electromagnetic waves.



4. Apparatus in accordance with Claim 1, wherein said second switch and said third switch independently control operation of said first switch.

5. Apparatus in accordance with Claim 4, wherein said second switch and said third switch are connected in parallel.

6. Apparatus in accordance with Claim 1, wherein said second switch and said third switch are cooperatively connected to control operation of said first switch.

7. Apparatus in accordance with Claim 6, wherein said second switch and said third switch are connected in series.

8. Apparatus in accordance with Claim 1, wherein said responsive means includes means for activating said third switch in response to a first radiation signal and for deactivating said third switch in response to a subsequent second radiation signal.



9. Apparatus in accordance with Claim 1, wherein said responsive means includes means for activating said third switch only while responding to a radiation signal.

10. Apparatus for remotely controlling electrical equipment, which comprises:

a ground fault interrupter circuit having first means selectively operable for connecting and disconnecting a source of power to the electrical equipment; and

second means responsive to electromagnetic radiation for selectively operating said first means.

11. Apparatus in accordance with Claim 10., wherein said electromagnetic radiation is comprised of a carrier signal and a modulating signal and wherein said second means is responsive to the modulating signal.

12. Apparatus in accordance with Claim 11, wherein said second means includes:

third means for receiving the electromagnetic radiation and for generating a composite signal having a first component with a frequency equal to the carrier signal and a second component with a frequency equal to the modulating signal; and

a mixer/oscillator having a local frequency equal to the frequency of the carrier signal and responsive to the composite signal for generating a



demodulated signal having the same frequency as the modulating signal.

13. Apparatus in accordance with Claim 12, wherein said second means further includes:

a square wave generator responsive to the demodulated signal from the mixer/oscillator for generating a square wave output signal having the same frequency as that of the demodulated signal;

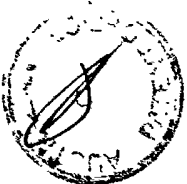
a wave shaping circuit responsive to the square wave generator for creating a trigger pulse having a leading edge;

a flip-flop responsive to said leading edge of said trigger pulse for changing its state; and

an output transistor responsive to a change in the state of said flip-flop for turning on or off.

14. Apparatus in accordance with Claim 13, wherein said square wave generator includes an operational amplifier.

15. Apparatus in accordance with Claim 13, wherein said wave shaping circuit includes a diode for rectifying said square wave output signal of said square wave generator and a capacitor for charging to the peak value of said square wave output signal.



16. Apparatus in accordance with Claim 11, wherein said first means includes:

a circuit breaker;

a relay for operating the circuit breaker;

a first transistor for operating the relay; and

an electronic latch circuit for turning said first transistor off and maintaining said first transistor off when said electronic latch circuit is latched.

17. Apparatus in accordance with Claim 16, wherein said second means includes:

fourth means for receiving the electromagnetic radiation and for generating a composite signal having a first component with a frequency equal to the carrier signal and a second component with a frequency equal to the modulating signal; and

a mixer/oscillator having a local frequency equal to the frequency of the carrier signal and responsive to the composite signal for generating a demodulated signal having the same frequency as the modulating signal.

18. Apparatus in accordance with Claim 17, wherein said second means further includes:

a square wave generator responsive to said demodulated signal from said mixer/oscillator for generating a square wave output signal having the same frequency as that of the demodulated signal;



a wave shaping circuit responsive to the square wave generator for creating a single trigger pulse; and

a flip-flop responsive to a leading edge of the trigger pulse for changing its state and a second transistor responsive to a change in state of the flip-flop for turning on or off, the second transistor being connected to the electronic latch circuit such as to unlatch the electronic latch circuit when the second transistor is on to thereby allow the first transistor to turn on.

19. Apparatus in accordance with Claim 18, further including a transmitter for selectively generating the electromagnetic radiation.

20. Apparatus in accordance with Claim 19, wherein the transmitter includes:

an oscillator for generating the modulating signal;

a mixer/oscillator for generating the carrier signal and for modulating the amplitude of the carrier signal with the modulating signal; and

an antenna responsive to the mixer/oscillator for generating the electromagnetic radiation.

21. Apparatus in accordance with Claim 20, wherein the transmitter further includes a switch for applying power to the oscillator and the mixer/oscillator for an interval of time to generate a burst of electromagnetic radiation.



22. Apparatus in accordance with Claim 21, wherein the means for selectively operating the connecting and disconnecting means is responsive to a single burst of electromagnetic radiation for turning off the equipment and responsive to two bursts of electromagnetic radiation for turning on the electrical equipment.

23. Apparatus for remotely controlling electrical equipment, which comprises:

a ground fault interrupter circuit having means selectively operable for connecting and disconnecting a source of power to the electrical equipment;

a transmitter for generating electromagnetic radiation when it is desired to operate the connecting and disconnecting means; and

means responsive to electromagnetic radiation for selectively operating the connecting and disconnecting means.

24. Apparatus in accordance with Claim 23 wherein the electromagnetic radiation is comprised of a carrier signal and a modulating signal and wherein the means for selectively operating the connecting means is responsive to the modulating signal.



25. Apparatus in accordance with Claim 24, wherein the means for selectively operating the connecting and disconnecting means includes:

means for receiving the electromagnetic radiation and for generating a composite signal having a first component with a frequency equal to the carrier signal and a second component with a frequency equal to the modulating signal; and

a mixer/oscillator having a local frequency equal to the frequency of the carrier signal and responsive to the composite signal for generating a demodulated signal having the same frequency as the modulating signal.

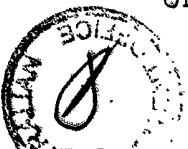
26. Apparatus in accordance with Claim 25, wherein the means for selectively operating the connecting and disconnecting means further includes:

a square wave generator responsive to the demodulated signal from the mixer/oscillator for generating a square wave output signal having the same frequency as that of the demodulated signal;

a wave shaping circuit responsive to the square wave generator for creating a single trigger pulse;

a flip-flop responsive to a leading edge of the trigger pulse for changing its state; and

an output transistor responsive to a change in the state of the flip-flop for turning on or off.



27. Apparatus in accordance with Claim 26, wherein the square wave generator includes an operational amplifier.

28. Apparatus in accordance with Claim 27, wherein the wave shaping circuit includes a diode for rectifying the square wave output signal of the square wave generator and a capacitor for charging to the peak value of the square wave output signal.

29. Apparatus in accordance with Claim 28, wherein the transmitter includes:

an oscillator for generating the modulating signal;

a mixer/oscillator for generating the carrier signal and for modulating the amplitude of the carrier signal with the modulating signal; and

an antenna responsive to the mixer/oscillator for generating the electromagnetic radiation.

30. An apparatus for remotely controlling electrical equipment, the apparatus substantially as hereinbefore described with reference to the accompanying drawings.

Dated this 14th day of August, 1995

FELCHAR MANUFACTURING CORPORATION
By their Patent Attorney
GRIFFITH HACK & CO.



ABSTRACT OF THE DISCLOSURE

Apparatus for remotely controlling electrical equipment includes a ground fault interrupter circuit having a selectively operable circuit breaker for
5 connecting and disconnecting power to the electrical equipment, a transmitter for generating amplitude modulated electromagnetic radiation when it is desired to operate the circuit breaker, and a receiver responsive to the electromagnetic radiation for selectively
10 operating the circuit breaker.

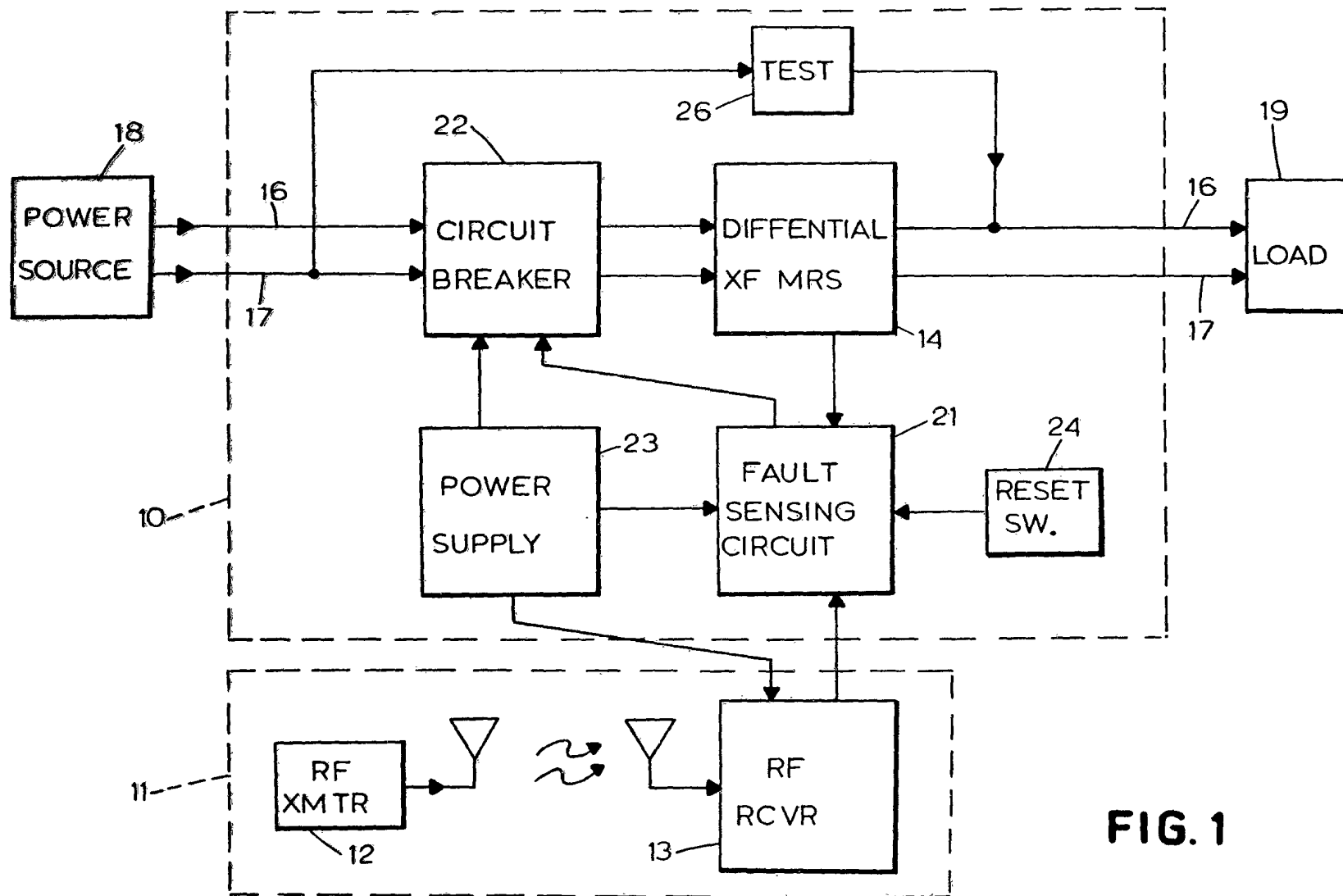
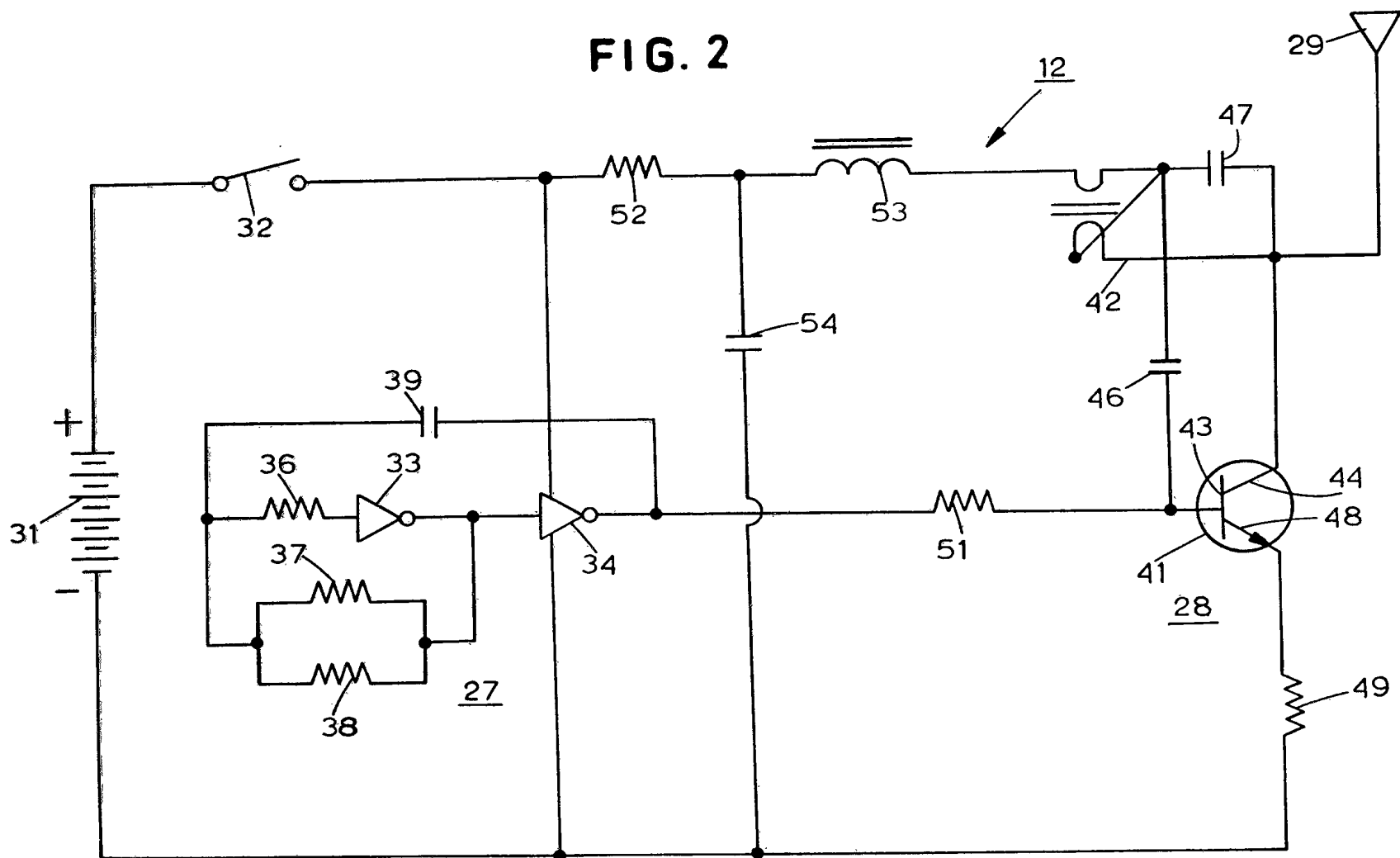


FIG. 1

FIG. 2



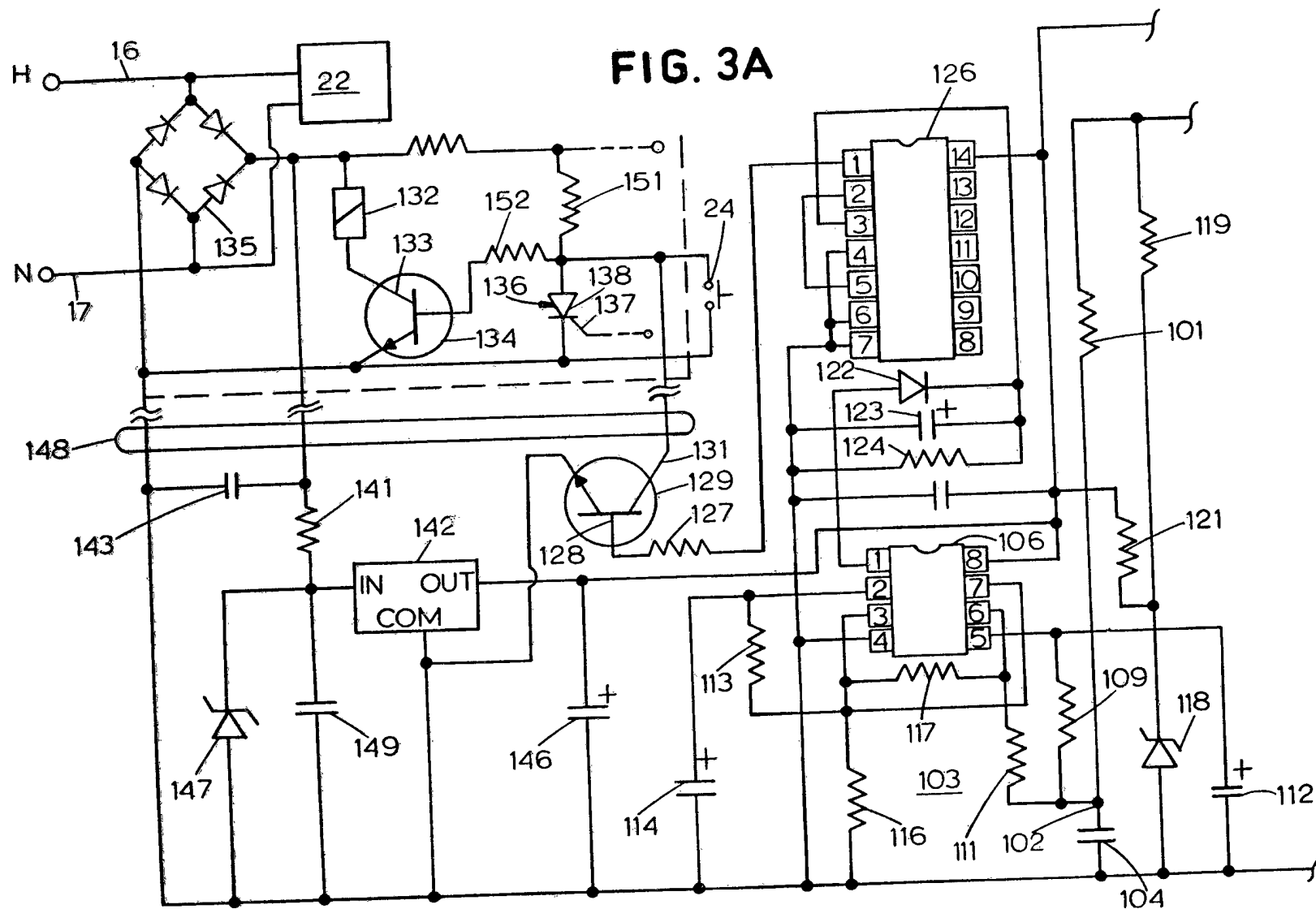


FIG. 3B

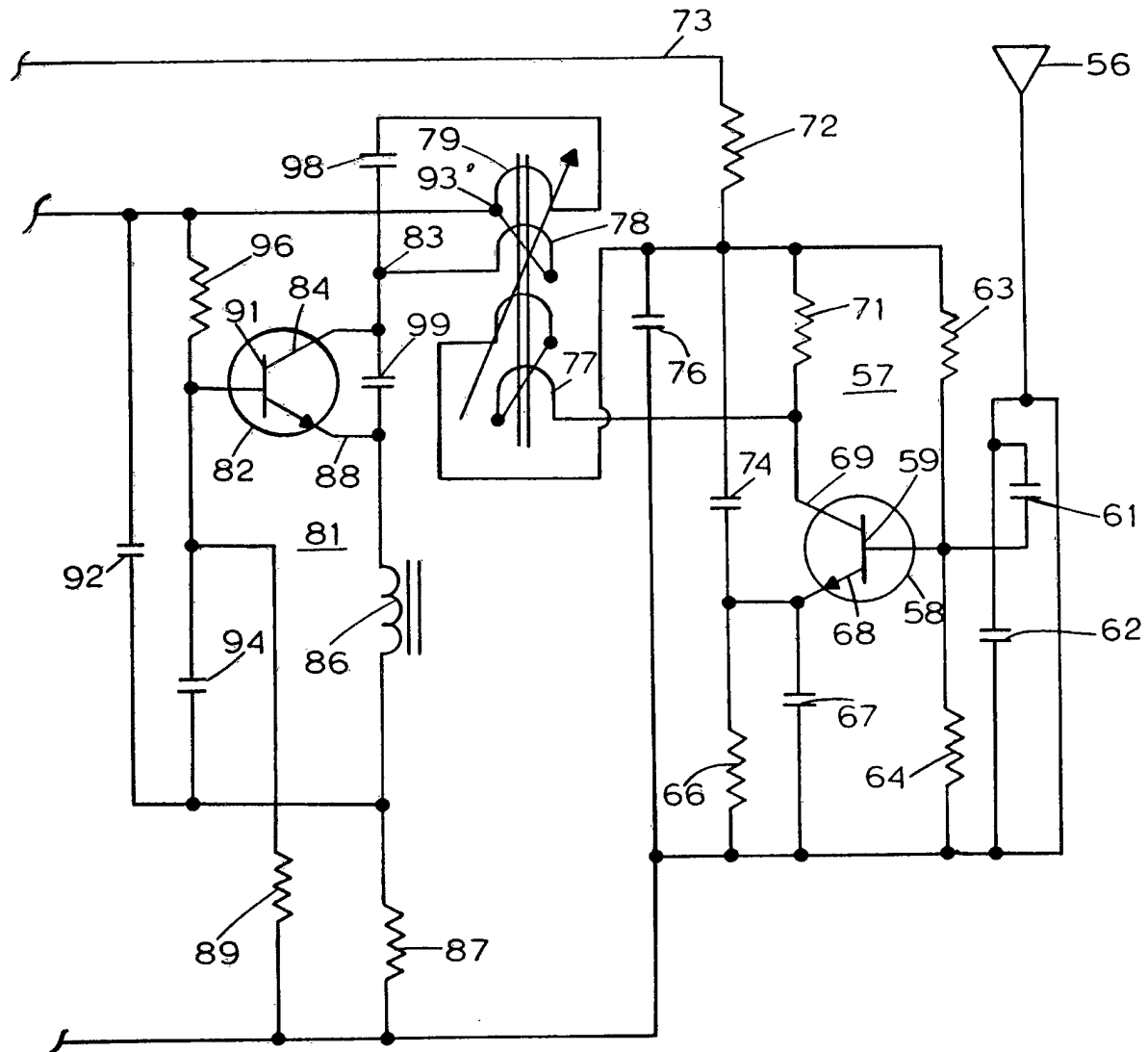


FIG. 4

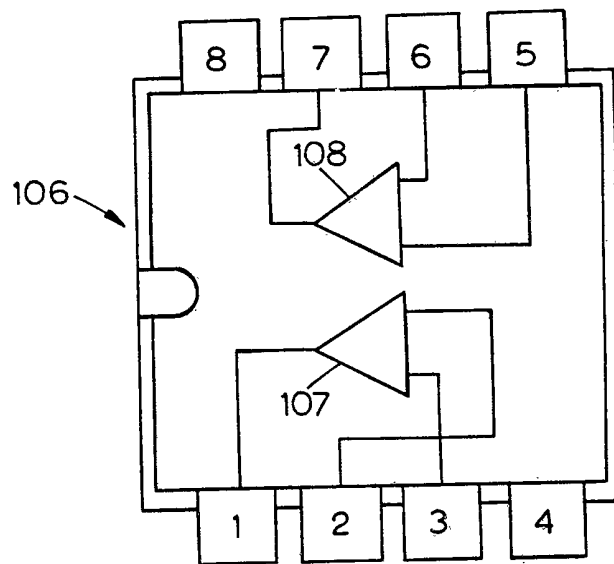


FIG. 5

