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[54] **ELECTROSURGICAL UNIT**

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[52] **U.S. Cl.** **128/303.14**

[51] **Int. Cl.** **A61n 3/02**

[58] **Field of Search**..... 128/303.13, 303.14, 303.17, 128/303.18, 421, 422, 423, 2.1 P

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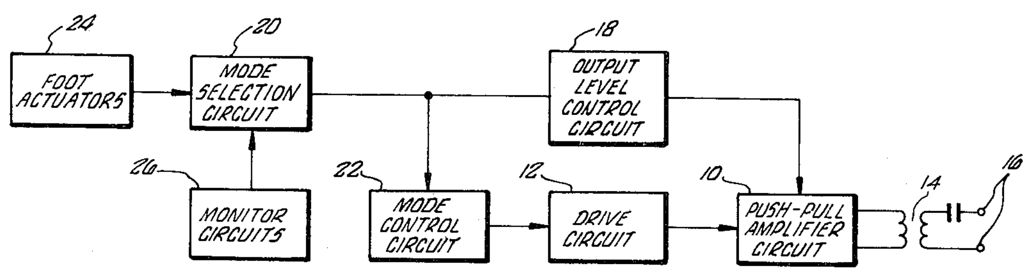
Primary Examiner—William E. Kamm

[57] **ABSTRACT**

An electrosurgical unit for generating electrical signals intended for application to the body of a patient via an electrosurgical electrode, is disclosed. Cutting signals and coagulation signals, as well as a blend of both signals, are generated by the unit under the control of a mode control circuit that is responsive to the operation of selector switches and/or manually operated actuators. Selected patient and unit conditions are monitored to have the electrosurgical unit disabled under certain dangerous conditions.

26 Claims, 6 Drawing Figures



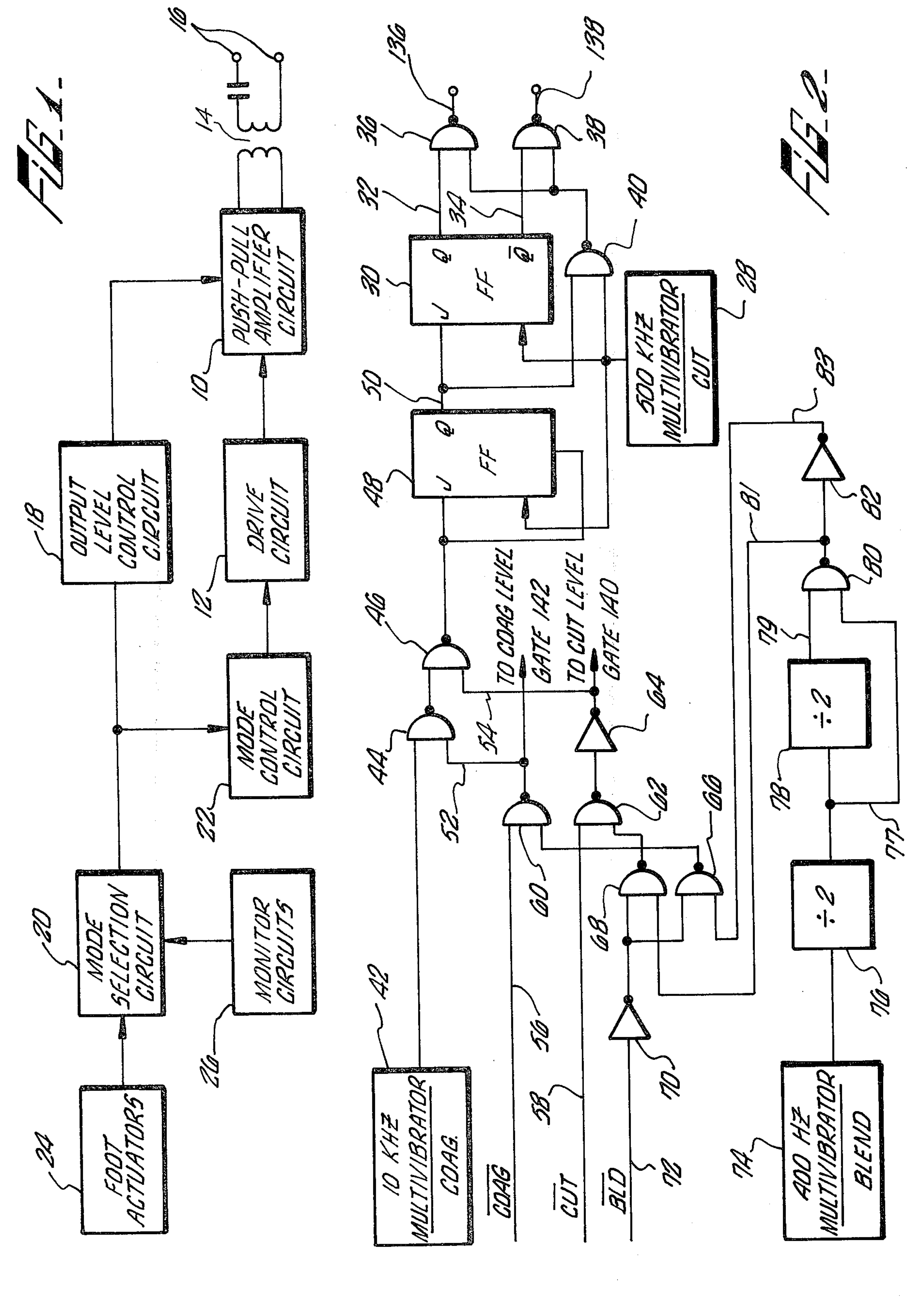

FOOT ACTUATORS
MODE SELECTION CIRCUIT
MONITOR CIRCUITS
OUTPUT LEVEL CONTROL CIRCUIT
MODE CONTROL CIRCUIT
DRIVE CIRCUIT
PUSH-PULL AMPLIFIER CIRCUIT
10 KHZ MULTIVIBRATOR COAG.
500 KHZ MULTIVIBRATOR CUT
400 HZ MULTIVIBRATOR BLEND
FF
FF
÷2
÷2
TO COAG LEVEL GATE 142
TO CUT LEVEL GATE 140
COAG
CUT
BLD

FIG_1.

FIG_2.

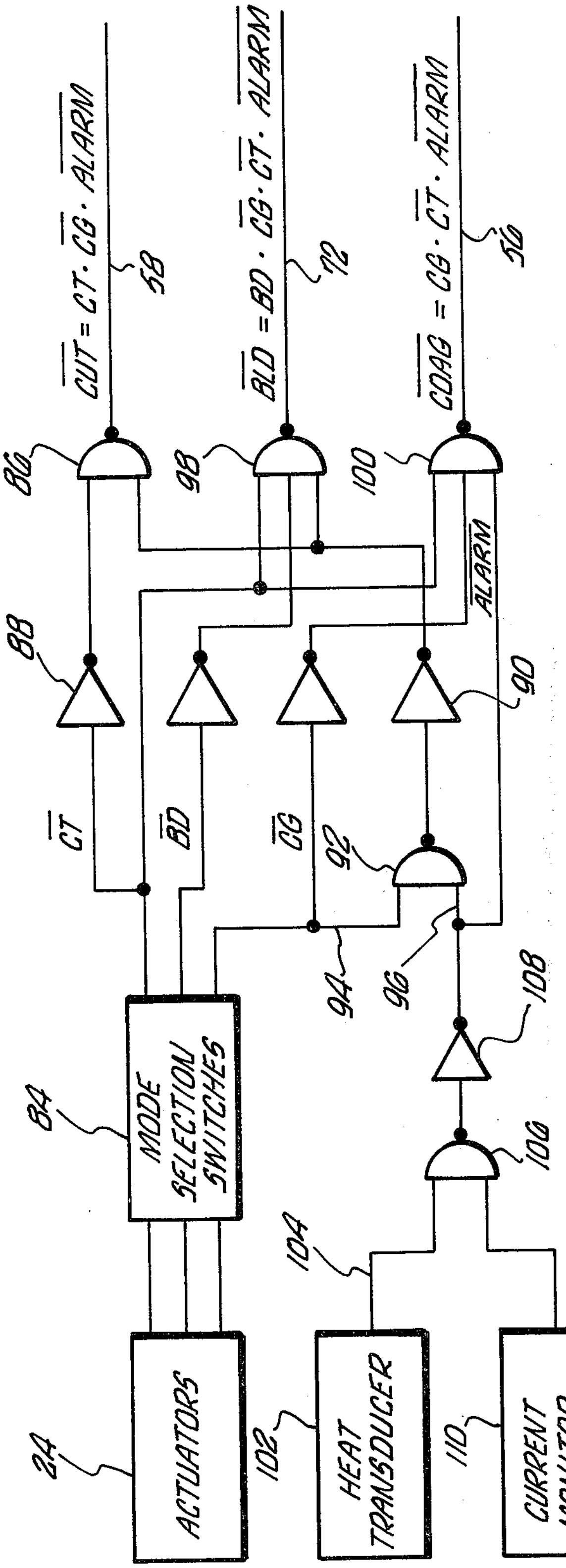

CUT = CT · CT · CG · ALARM
BLD = BD · CG · CT · ALARM
COAG = CG · CT · ALARM
58
72
56
86
98
100
88
90
92
94
96
106
108
ALARM
CT
BD
CG
MODE SELECTION SWITCHES
84
ACTUATORS
24
HEAT TRANSDUCER
102
104
CURRENT MONITOR
110

FIG. 3

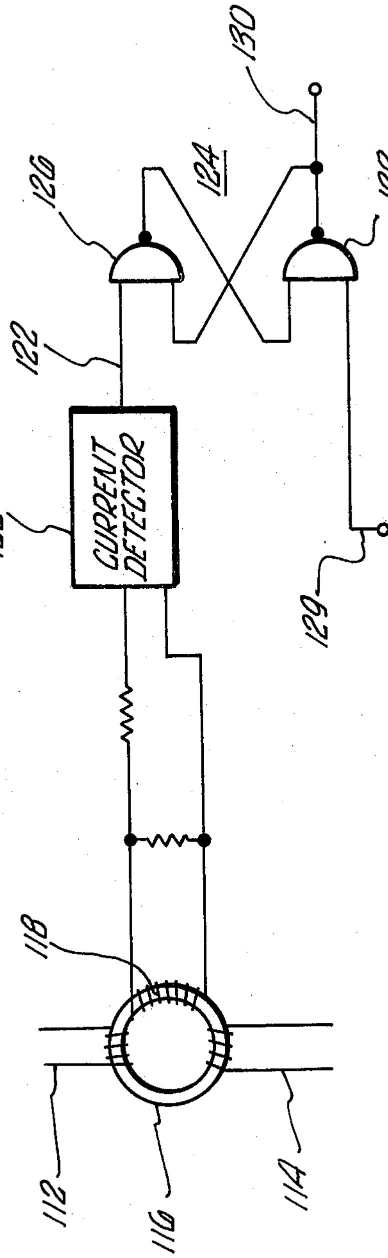

CURRENT DETECTOR
120
122
124
126
128
130
129
RESET
118
116
112
114

FIG. 4

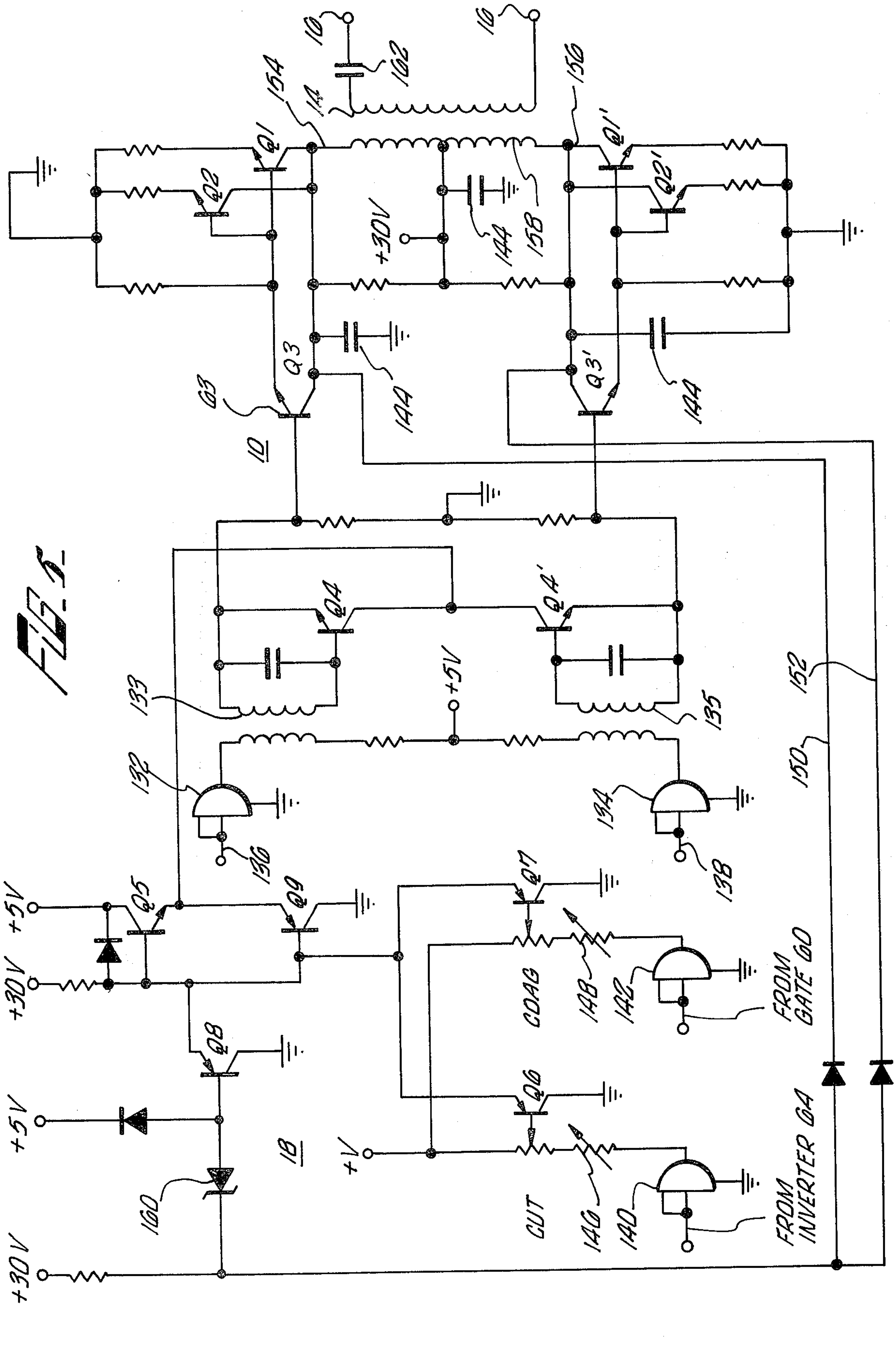
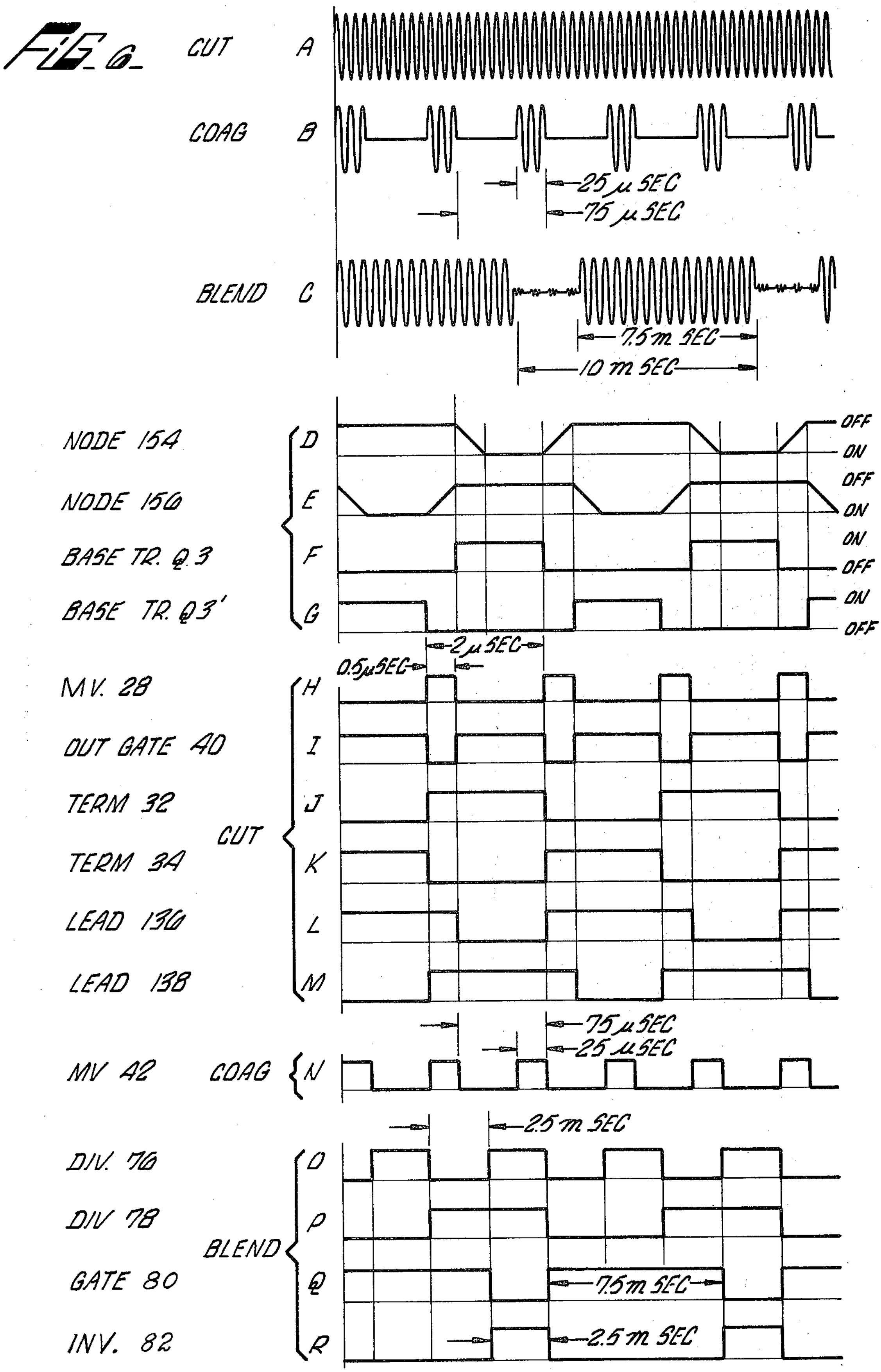

Q1
Q2
Q3
Q1'
Q2'
Q3'
Q4
Q4'
Q5
Q6
Q7
Q8
Q9
+30V
+5V
+V
COAG
CUT
FROM GATE 60
FROM INVERTER 6A
10
16
14
18
154
156
158
162
144
132
133
134
135
136
138
140
142
146
148
150
152
160

FIG. 6


CUT A
COAG B
25 µ SEC
75 µ SEC
BLEND C
7.5 m SEC
10 m SEC
NODE 154 D
NODE 156 E
BASE TR. Q 3 F
BASE TR. Q 3' G
OFF
ON
0.5µSEC
2 µ SEC
M.V. 28 H
OUT GATE 40 I
TERM 32 J
CUT
TERM 34 K
LEAD 136 L
LEAD 138 M
75 µ SEC
25 µ SEC
MV 42 COAG N
2.5 m SEC
DIV. 76 O
DIV 78 P
BLEND
GATE 80 Q
7.5 m SEC
INV. 82 R
2.5 m SEC

ELECTROSURGICAL UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to electrosurgical units. More specifically, the present invention concerns an improved electrosurgical unit that operates to generate high power electrical signals for use in performing electrosurgery.

2. Description of the Prior Art

A variety of electrosurgical units are available in the prior art. These units function to permit surgical cutting and/or coagulation electrically. Three different signals are characteristically generated and used. These signals may be referred to as cutting signals, coagulation signals, or blended signals formed by combining both the cutting and coagulation signals. Such signals are applied to a patient, conducted through the patient's body, and returned to the unit via a ground path provided by an "indifferent" pad that is maintained in contact with the patient.

Generally described, the cutting signal is a high frequency signal that serves to cut when applied to a patient. An electrosurgical electrode is used to apply the electrical energy to definitely defined and concentrated points of a patient's body. As is well known, cutting is accomplished by the concentrated application of high frequency electrical energy which effectively destroys the body cells directly beneath the electrosurgical electrode.

Coagulation signals are intended to produce coagulation by shrinking vessel walls. Typically such coagulation signals are pulses of energy having a damped sinusoidal waveform. Generally, coagulation signals may be viewed as causing cell dehydration to produce coagulation rather than destroying cells in the fashion of cutting signals.

Blended signals formed by combining cutting and coagulation signals are useful for accomplishing cutting and coagulation at the same time. Alternating periods of each signal may be used to form the blended signals.

As may be readily appreciated, the application of large amounts of electrical power to a human body presents the potential for serious burning. Consequently, the power level of electrosurgical signals must be accurately controlled.

Prior art units are generally not as stable and readily controllable as is desirable to promote maximum safety. The reason is that "tube" type circuits have been necessarily used to produce the cutting and coagulation signals due to the high power levels involved, i.e., 450 watts output, and the inability to generate the earlier mentioned damped sinusoidal pulses with solid-state circuits.

As is well known, such tube-type circuits vary in output power as a function of the condition and age of the tubes, i.e., as the tubes age and deteriorate the output power changes.

Such aging of electronic tubes is continuous and consequently the power generated by such circuits also is continually changing to effectively frustrate stability and accurate control. As a result, a not uncommon result is over or under coagulation with the attendant medical complications.

It is thus the intention of the subject invention to provide an improved electrosurgical unit that overcomes the disadvantages of prior art units by providing a greater amount of electrical power for electrosurgical use than heretofore possible, being stable and accurately controllable, being compatible with solid state technology, and being of reduced size and weight to more readily permit repositioning of the unit by medical personnel.

SUMMARY OF THE INVENTION

Briefly described, the present invention involves an electrosurgical unit for providing cutting, coagulation and blended signals suitable for use in performing surgical cutting or coagulation or a combination of both.

More particularly, the subject electrosurgical unit includes circuitry for providing high frequency, high power electrical signals for cutting, pulses of said high frequency signals for coagulation, and a blend of the two signals when desired. Generation of each of the signals is controlled by mode control and selection circuitry that is in turn responsive to hand or foot operated actuators. Output level control circuits are used to permit control of the amplitude level of the cutting and coagulation signals individually. Circuits for continually monitoring certain patient and unit conditions may be connected to disable the electrosurgical unit in response to the detection of undesired conditions.

The objects and many attendant advantages of the present invention will be more readily appreciated as the same becomes better understood by reference to the following detailed description which is to be considered in conjunction with the accompanying drawings wherein like reference symbols designate like parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram generally illustrating an electrosurgical unit in accordance with the present invention.

FIG. **2** is a schematic block diagram illustrating exemplary drive and mode control circuitry that may be used in conjunction with the present invention.

FIG. **3** is a schematic block diagram illustrating exemplary circuitry that may be used to provide mode control signals in accordance with the present invention.

FIG. **4** is a schematic diagram illustrating an exemplary electrode monitoring arrangement that may be used in conjunction with the present invention.

FIG. **5** illustrates exemplary level control and output amplifier circuits that may be used in conjunction with the present invention.

FIG. **6** is a graphic diagram illustrating a number of waveforms that are useful in describing the operation of the subject invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1** of the drawings, an electrosurgical unit in accordance with the present invention essentially includes a push-pull amplifier **10** that is connected to be driven by pulses provided by a drive circuit **12.** Output signals provided by the amplifier circuit **10** are applied through a coupling transformer **14** to a pair of output terminals **16.** Any conventional electrosurgical electrode (not shown) may be connected to the terminals **16** for applying electrical energy to a patient. The level of the output signals provided by the amplifier **10** are controlled by an output level control circuit **18** that is selectively operated in response to mode selection signals provided from a mode selection circuit **20.** Such mode selection signals are also applied to a mode control circuit **22** to have appropriate drive pulses developed by the drive circuit **12.** manually operated actuators **24** may be connected to the mode selection circuit **20** for controlling the output of such mode selection signals. Selected monitoring circuits **26** may be connected to provide alarm signals which disable the electrosurgical unit.

Referring briefly to the waveforms of FIG. **6,** cutting signals provided by an electrosurgical unit in accordance with the invention involve high frequency, high power signals. As an example, the cutting signals illustrated by waveforms A may have a frequency of 250kHz. The output power may be controlled to be as high as is necessary to perform the desired cutting. For example, an electrosurgical unit has been designed to provide up to 600 watts of cutting power.

Coagulation signals, as illustrated by waveform B, involve short pulses, or bursts, of the high frequency signals used for cutting. The power level of coagulation signals is usually decreased considerably from the level that is used for cutting. As an example, it has been empirically found that 25 microsecond pulses of high frequency energy occurring at 75 microsecond intervals will efficiently produce coagulation.

Blended signals, as illustrated by waveform C, are formed by including alternate periods of cutting signals and coagulation signals. As shown, a 10 millisecond duty cycle may be used wherein coagulation signals are provided for 2.5 milliseconds and cutting signals are provided for 7.5 milliseconds. The blended signals would be used to produce coagulation as cutting progresses.

Referring again to FIG. **1,** the 250kHz high frequency signals are provided by the amplifier circuit **10** in response to drive pulses that are provided by the drive circuit **12.** The coagulation signals are provided by allowing the drive circuit **12** to operate for 25 microsecond periods and be disabled for 75 microsecond intervals following each operation period of 25 microseconds. The blended signals would be produced by alternately operating the drive circuit **12** between the cut mode and the coagulation mode. The different amplitude levels to be used for the cutting and coagulation signals are independently controlled by the output level control circuit **18** in a manner described in greater detail hereinafter.

An exemplary drive circuit **12** and mode control circuit **22** is illustrated by FIG. **2.** As shown, a 500kHz multivibrator circuit is connected to provide pulses to clock a flip-flop circuit **30.** The pulses provided by the multivibrator **28** are illustrated by waveform H of FIG. **6** wherein 0.5 microsecond pulses occur every 2 microseconds. The output signals at the Q and Q output terminals **32** and **34,** respectively, of the flip-flop **30** alternately change between high and low levels with each succeeding pulse from the multivibrator as shown by waveforms J and K of FIG. **6.**

For the purposes of this application, a NAND gate as hereinafter referred to is understood to provide a high output signal whenever any of its inputs is a low signal and provide a low output signal only when all input signals are high.

The output terminals **32** and **34** of the flip-flop **30** are connected as one of two inputs to a pair of NAND gates **36** and **38,** respectively. The pulses from the multivibrator **28** are applied as a second input signal to the NAND gates **36** and **38** via a NAND gate **40** which effectively serves as an inverter as may be observed from the waveforms H and I of FIG. **6.**

Assuming that the enabling input signal applied to the J input terminal of the flip-flop **30,** and to the NAND gate **40** is continually high, the output of the NAND gate **40** will be high for the time interval between successive pulses from the multivibrator **28** and low for the duration of each of the multivibrator pulses as shown by waveform I. Consequently, the NAND gates **36** and **38** will alternately provide low signals for the periods between successive pulses from the multivibrator **28** as shown by waveforms L and M, respectively. Otherwise considered, each of the NAND gates **36** and **38** will produce negative pulses at a 250kHz rate which, when applied to drie the push-pull amplifier circuit **10** as described in greater detail in conjunction with FIG. **5,** will produce the desired 250 kHz high frequency signals.

As earlier discussed, the coagulation signals may be simply viewed as pulses, or bursts, of the 250kHz high frequency signal that is used as a cutting signal wherein the bursts last for 30 microseconds and occur every 100 microseconds. Referring to FIG. **2,** this is accomplished by effectively cyclically disabling the flip-flop **30** for periods of 75 microseconds every 100 microseconds. This would require that the J input terminal of the flip-flop **30** alternately rerceive a low signal for a period of 75 microseconds followed by a high signal for a period of 25 microseconds. To this end, a multivibrator **42** is connected to provide 25 microsecond pulses at 100 microsecond intervals as shown by waveform N of FIG. **6.** Such pulses from the multivibrator **42** are applied through a pair of serially connected NAND gates **44** and **46,** and a flip-flop **48,** to the J input terminal of the flip-flop **30.** The NAND gates **44** and **46** serve to permit controlled application of the pulses from the multivibrator **42** to the flip-flop **30** as is hereinafter explained. Synchronism of cutting and coagulation signals is provided by having the flip-flops **30** and **48** both clocked by the multivibrator **28.**

Assuming that a high signal is provided to the respective NAND gates **44** and **46** at the respective input leads **52** and **54** thereof, the pulses from the multivibrator **42** will pass through both the gates **44** and **46.** However, if a low input signal is applied to the NAND gate **44** via the lead **52,** the pulses from the multivibrator **42** will be effectively blocked since the output of the NAND gate **44** will be maintained high regardless of the level of the signal applied thereto from the multivibrator **42.** Accordingly, high signals are applied to the gates **44** and **46** via the leads **52** and **54,** respectively, whenever coagulation signals are to be provided while a low signal is applied to the gate **44** whenever a coagulation signal is not desired. Similarly, a low signal is applied to the gate **46** when cutting signals are desired to have the flip-flop **30** and **48** set and reset by the pulses from the multivibrator **28.**

The above-described signals applied to the gates **44** and **46** via the leads **52** and **54,** respectively, are provided in response to coagulation and cutting mode selection signals appearing at the leads **56** and **58,** respectively. The coagulation mode selection signal applied to the lead **56** will be low as will be the cut mode selection signal when applied to the lead **58.** The leads **56** and **58** will receive high signals at all other times when no mode selection signals are present.

The coagulation mode selection signal appearing at the lead **56** is applied as an input to a NAND gate **60** to have the desired high input signal applied to the NAND gate **44** via the lead **52** during the coagulation mode. Similarly, a cut mode selection signal is applied to a NAND gate **62**, and an inverter **64** connected in series therewith, to have the desired low signal applied to the NAND gate **46** via the lead **54** during a cutting mode.

Desired blended signals are generated by alternately applying low signals to the NAND gates **60** and **62** from a pair of NAND gates **66** and **68**, respectively. This is accomplished in accordance with the earlier described timing sequence (see waveform C) by having the NAND gate **66** provide a low signal to the gate **60** for a period of 2.5 milliseconds for the coagulation period followed by having the NAND gate **68** provide a low signal to the gate **62** for a period of 7.5 milliseconds for the cutting period. The gates **66** and **68** are connected to receive a high input signal via an inverter **70** when a blend mode selection signal is applied to the inverter via the lead **72**. The desired timing sequence is controlled by input signals applied to the NAND gates **66** and **68** from a timing circuit including a multivibrator **74**. Pulses occurring at a rate of 400Hz are provided by the multivibrator **74**. A pair of dividers **76** and **78** may be used to provide pulsed signals having reduced rates of 200Hz and 100Hz at the respective output terminals **77** and **79**, thereof. Such 200Hz and 100Hz signals are illustrated by waveforms O and P.

As shown by waveform O, the 200Hz pulsed signals provided by the divider **76** include 2.5 millisecond pulses occurring at 5 microsecond intervals while the 100Hz signal includes 5 millisecond pulses occurring at 10 millisecond intervals. When such 200Hz and 100Hz signals are applied as inputs to a NAND gate **80** via the leads **77** and **79**, the output of the gate **80** will be cyclically maintained high for 7.5 milliseconds and low for 2.5 microseconds as shown by waveform Q of FIG. **6**. An inverted waveform is provided by an inverter circuit **82** as shown by FIG. **6**, waveform R. The respective outputs of the NAND gate **80** and the inverter **82** are applied as inputs to the NAND gates **68** and **66** via leads **81** and **83**. The gate **68** thus applies a low signal to the gate **62** to have cutting signals generated for a period of 7.5 milliseconds followed by the NAND gate **66** applying a low signal to the gate **60** to have coagulation signals generated for a period of 2.5 milliseconds.

The three mode selection signals necessarily applied to the leads **56, 58** and **72,** to operate the mode control circuit **22** to have desired cutting, coagulation or blended signals generated, are provided from the mode selection circuit **20** in response to operation of the actuators **24.**

An exemplary foot operated actuator may involve an arrangment of three individual pedals, or the like, which ultimately cause a desired mode selection signal to be provided at the appropriate one of the leads **56,** 58 and **72** when a pedal is depressed or otherwise operated. Such foot operated actuators are well known and a detailed discussion of such actuators is not deemed necessary for the purpose of this description. A hand operated actuator may be used to perform the same functions.

As shown by FIG. **3,** the mode selection circuit **20** includes a bank of mechanical switches **84** that are manually operable and which serve to pass or stop signals provided by operation of the foot actuators **24.** For example, four switch positions may be provided for CUT ONLY, COAGULATION ONLY, BLEND ONLY, and CUT-COAGULATE-BLEND. In the first three positions, only operation of the mode pedal corresponding to the position of the switch **84** will be effective. In the last position any pedal may be effectively operated.

The selection switch **84** may simply involve opening the conductive path for non-selected modes and closing the conductive path for the selected mode. For example, where only the cut mode is desired, the switches **84** would be placed in the CUT ONLY position. The circuit for the cut mode would be closed while all other switches would be open.

The signals provided by the actuators **24** via the mode selection switches **84** are applied to an array of NAND gates that are essentially connected to form a decoder. As shown in FIG. **3**, a cut mode selection signal would appear at the lead **58** at the output of a NAND gate **86** whenever certain input signals summarized by the equations appearing in FIG. **3** are applied. For Example, the equation $\overline{CUT} = CT \cdot \overline{CG} \cdot \overline{ALARM}$ indicates that the desired low level cut mode selection signal will be provided by gate **86** in response to the simultaneous application of input signals representing a cut signal, a lack of a coagulation signal, and a lack of an alarm signal. The cut signal would be high and would be provided via an inverter **88.** The signal indicating the lack of a coagulation signal and the lack of an alarm signal is provided at the output of an inverter **90** which is connected to receive the output of a NAND gate **92** connected to receive as inputs a high signal via a lead **94** representing $\overline{CG}$ and a high signal via a lead **96** representing the lack of an alarm condition ($\overline{ALARM}$).

Similarly, a blend mode selection signal is provided at the lead **72** at the output of a NAND gate **98** and a coagulation mode selection signal is provided at the lead **56** at the output of a NAND gate **100** in accordance with the equations shown in FIG. **3.**

As may be noted, the $\overline{ALARM}$ signal may be directly applied to each of the NAND gates **86, 98** and **100** as a high level signal under normal non-alarm conditions. This high level signal permits the respective NAND gates **86, 98** and **100** to respond in a routine fashion to any low level signals applied thereto. However, should an alarm condition occur, the $\overline{ALARM}$ signal is replaced by a low ALARM signal which would be applied to each of the NAND gates **86, 98** and **100.** The result is that each of these gates **86, 98** and **100** will provide a high output signal regadless of the presence or absence of any mode selection signals. The result is that the electrosurgical unit is effectively disabled until the ALARM signal is removed by the detected dangerous condition being remedied.

Any number of inherently dangerous conditions may be monitored and used to generate an ALARM signal which disables the electrosurgical unit. Exemplary of such monitoring schemes would be a heat transducer situated within the unit itself to monitor the temperature of certain component elements of the unit to detect when the temperature is at a level dangerous to to components and to the unit. For example, the temperature of a power transformer may be monitored to prevent overheating and consequent damage to circuit components.

A heat transducer circuit **102** is illustrated in FIG. **3** and is intended to provide a high signal at an output lead **104** under normal ambient conditions and a low signal whenever the temperature is detected to be at a predetermined dangerous level. Any conventional heat transducer circuit may be used. When the low signal is applied via the lead **104** as an input to a NAND gate **106,** a corresponding low output signal is provided at the output of an inverter **108** as an ALARM signal.

Another dangerous condition that may cause serious injury to a patient is an imbalance in the amount of current flowing from the electrosurgical unit through an active conductor to the electrosurgical electrode and the current flowing from the indifferent pad through ground conductor to a ground terminal of the unit. Under normal conditions the amount of current flowing through these two conductors is equal. An imbalance may indicate that current applied to the patient is exiting through a path other than the desired path provided by the indifferent pad. An example would be where the indifferent pad is not in proper contact with the patient and/or the patient is improperly grounded by having some part of the body in contact with an item such as the operating table at ground potential.

To detect such a dangerous condition, a current monitor **110** may be provided to generate an ALARM signal which is also applied to the NAND gate **106** as a low level signal to disable the electrosurgical unit in the manner previously described.

An exemplary current monitoring circuit is illustrated by FIG. **4.** As shown, an active conductor **112** connected to an electrosurgical electrode and a ground conductor **114** connected to an indifferent pad may be wound about a toroidal core **16.** A sensing winding **118** is also wound about the toroidal core. Unequal amounts of current flow through the conductors **112** and **114** will result in current flow through the sensing windings **118.** A current detector **120** of conventional design is connected to the windings **118** to detect the current flow therein and respond by providing a low output signal to a latching circuit **124** via an output lead **122.** In the exemplary circuit of FIG. **4,** the current detector **120** may be of the type that will provide an output signal whenever the current flow through the windings **118** exceeds a selected threshold current level.

The latching circuit **124** is of a conventional type including a pair of NAND gates **126** and **128.** The application of a low signal to the NAND gate **126** via the lead **122** causes the output of the gate **126** to be high. This high output of the gate **126** when applied as an input to the gate **128,** along with a high reset signal at the lead **129,** will cause the output of the latching circuit **124** at the terminal **130** to be low. As is typical of the illustrated latching circuit **124,** the output appearing at the terminal **130** will remain low until a low reset signal is applied to the gate **128** to reset the latching circuit. If the reset signal used is a momentarily low signal (a negative pulse), the output signal at the terminal **130** will remain high (return to normal) only if the alarm condition has been removed and the signal at the lead **122** is high. If a low signal continues to bbe applied as an input to the NAND gate **126** via the lead **122,** the output of the latching circuit will revert to a low signal after removal of the reset signal. As such, the electrosurgical unit may not be artificially reset to be made operative, without correction of the dangerous condition.

From the foregoing discussion, it is now apparent that operation of the foot actuators **24** will cause mode selection signals to be provided by the mode selection circuit **20** for controlling the mode control circuit **22,** and the level control circuit **18,** such that the driving pulses illustrated by waveforms L and M of FIG. **6** will be applied from the NAND gates **36** and **38** at the output leads **136** and **138,** respectively, to drive the push-pull amplifier circuit **10.**

Referring now to FIG. **5,** the push-pull amplifier circuit **10** may be observed to basically include a conventional transistorized push-pull amplifier circuit including complementary circuit halves formed by serially connected transistors **Q1, Q2, Q3,** and Q1′, Q2′, Q3′. The series connected amplifying transistors **Q1** and **Q2** are driven by the transistor Q3 which is in turn driven by an output transistor **Q4.** Similarly, the transistors Q1′ and Q2′ are driven by the transistor Q3′ which receives drive signals at the base thereof from an output transistor Q4′. The drive transistors Q3 and Q3′ are alternately driven in unison with the output transistors Q4 and Q4′, respectively, in response to the application of the pulses from the respective NAND gates **36** and **38** to the output gates **132** and **134** via leads **136** and **138,** respectively.

The gates **132** and **134** as well as the gates **140** and **142** to be later discussed, are of a conventional type wherein the application of prescribed low signals thereto enable the gates.

Referring again to the waveforms of FIG. **6,** the negative output pulse applied from the gate **36** (waveform L) will enable the gate **132** and thereby permit current flow through the primary coil of a coupling transformer **133.** The transistor Q4 will be rendered conductive by the resulting voltage across the secondary coil of the transformer **133** to have a positive drive voltage (shown by waveform F) applied to the base of the transistor Q3 from an accurately controlled voltage source including a transistor **Q5.** The transistors **Q3, Q2** and **Q1** will thus be rendered conductive as is illustrated by waveform D of FIG. **6.** Similarly, the negative pulses from the NAND gate **38** (see waveform M) will enable the gate **134** to permit current flow through the primary coil of a coupling transformer **135.** The transistor Q4′ will thus be rendered conductive and positive drive signals will be applied to the base of the transistor Q3′. The transistors Q3′, Q2′ and Q1′ will thus be rendered conductive and non-conductive (as shown by waveform E) at alternte time intervals with the transistors Q3, Q2 and **Q1.** An essentially sinusoidal waveform is provided at the output terminals **16** via the output transformer **14** in that harmonics are for the most part eliminated in the operation of the amplifier **10.**

The push-pull amplifier **10** may be provided with an appropriate number of capacitors **144** to provide filtering of any high frequency ripple from the power supply connected thereto. It is to be understood that although only series of two amplifying transistors Q1 and Q2 and Q1′ and Q2′ have been illustrated, that each half of the push-pull amplifier **10** may include a series of as many transistors as is required to satisfy desired output power requirements of a unit. For example, it has been found that as many as eight transistors may be readily connected in parallel in the manner exemplified by the transistors Q1 and Q2 or Q1′ and Q2′ to provide an output power level of 600 watts.

The amplitude level of the signals provided at the output terminals **16** are controlled by a cut level control circuit including a transistor Q6 for cut signals and a coagulation level control circuit including a transistor Q7 for coagulation signals. The level control circuits also include variable resistors **146** and **148** which are respectively connected to control the base voltage of the transistors Q6 and Q7. Each of these resistors **146** and **148** is of the type that may be manually adjusted by a user of an electrosurgical unit. As shown, the gates **140** and **142** are connected to be enabled by the application of mode selection signals from the NAND gate **64** and the interver **60**, respectively. Accordingly, the cut and coagulation level control circuits will be operative only during the periods of time during which cutting or coagulating signals to be controlled are being provided at the output terminal **16**.

As earlier mentioned, the transistor Q5 is connected to function as an accurate voltage source that provides bias voltage to the collectors of the output transistors Q4 and Q4′. The bias voltage provided by the transistor Q5 is controlled by the operative one of the two level control circuits including the transistors Q6 and Q7.

The amplifier **10** is operated in a non-saturated mode by a pair of feedback leads **150** and **152** that are respectively connected between the nodes **154** and **156**, at the ends of the primary coil **158** of the output transformer **14**, and the cathode of a zener diode **160**. As the voltage at the nodes **154** and **156** approaches a voltage level set by the zener diode **160**, i.e., 3 volts, a transistor Q8 having its base connected to the zener diode **160** is rendered conductive. The transistor Q5 is hence rendered non-conductive and the transistors Q4 and Q4′ cease providing additional drive voltage to the base of the transistors Q3 and Q3′, respectively. The transistor Q9 is briefly rendered conductive and acts to drain any residual voltage stored on the energized one of the secondary coils of the coupling transformers **133** and **135**.

Any suitable power supply circuit may be used with the subject invention to provide the required biasing and other indicated voltges. Needless to state, the multivibrator circuits **28**, **42** and **74** may be of any conventional type wherein the duration and frequency of pulses provided may be adjusted as desired.

A capacitor **162** is illustrated as being connected in one of the leads to the output terminals **16**. Such a capacitor **162** provides D.C. isoltion to prevent the application of direct current to a patient and thereby preclude unexpected muscular reactions by a patient undergoing electrosurgery.

From the foregoing description, it is now clear that the present invention provides an improved electrosurgical unit that provides output signals for which the voltage levels are consistent, accurately controllable, and not subject to degradation and fluctuaton resulting from deterioration of included electronic tubes.

While a preferred embodiment of the present invention has been described hereinabove, it is intended that all matter contained in the above description and shown in the accompanying drawings be interpreted as illustrative and not in a limiting sense and that all modifications, constructions and arrangements which fall within the scope and spirit of the invention may be made.

What is claimed is:

1. An electrosurgical unit for generating electrical signals to be applied to the body of a patient by an electrosurgical electrode for producing surgical cutting and coagulation as selected, said electrosurgical unit comprising:

a pair of output terminals adapted to be coupled to the electrosurgical electrode;

first means for providing a continuous alternating current cutting signal having a selected freuency that produces surgical cutting when applied to the body of a patient;

second means for cyclically disabling said first means to provide a coagulating signal that is a succession of bursts of said alternating current signal, said coagulating signal providing coagulation when applied to the body of a patient;

third means for altering the disabling cycle of said second means to extend the length of time said first means operates and to provide a blended signal that alternately produces cutting and coagulation when applied to the body of a patient; and

output means for applying the blended signal to the output terminals.

2. The electrosurgical unit defined by claim **1**, said first means including:

drive means for providing drive pulses at a pulse rate corresponding to the frequency of said alternating current signal; and

wherein the output means is responsive to said drive pulses for providing said alternating current signal at the output terminals.

3. The electrosurgical unit defined by claim **2**, said drive means including:

a first multivibrator for providing pulses at a rate that is twice said selected frequency;

a bistable means having two states and producing output signals corresponding to each of two states thereof, said bistable device being switched between said two states in response to said pulses from said first multivibrator; and

gating means connected to be responsive to said first multivibrator pulses and to the output signals of said bistable device for providing said drive pulses.

4. The electrosurgical unit defined by claim **3**, said gating means including:

first and second NAND gates each receiving from said bistable device an output signal corresponding to a different one of said two states; and

a third NAND gate connected to be responsive to said first multivibrator for simultaneously providing to said first and second NAND gates an input signal corresponding to an inversion of said pulses from said first multivibrator.

5. The electrosurgical unit defined by claim **3**, said second means including a second multivibrator connected to distable said bistable device for predetermined time periods at predetermined time intervals, said bistable device being prevented from providing said drive pulses to said gating means when disabled.

6. The electrosurgical unit defined by claim **5**, said third means including means for alternately permitting and preventing, in accordance with a predetermined timing sequence, said second multivibrator from disabling said bistable device for said predetermined time periods at said predetermined time intervals.

7. The electrosurgical unit defined by claim **2,** further including inductive coupling means for providing said drive pulses to said output means.

8. The electrosurgical unit defined by claim **2,** said output means including:

a transistorized push-pull amplifier responsive to said drive pulses; and

a coupling transformer for inductively coupling the output of said push-pull amplifier to said output terminals.

9. The electrosurgical unit defined by claim **8** further including mode selection means for providing mode selection signals to control the operation of said first, second, and third means to provide cutting signals, coagulation signals, or blended signals.

10. The electrosurgical unit defined by claim **9,** further including manually operable actuator means for controlling the selection and generation of desired signals by said unit.

11. The electrosurgical unit defined by claim **8,** wherein the push-pull amplifier includes a pair of inputs and an output and wherein the output means includes feedback means coupled between the output and inputs of the amplifier for altering the voltage level at the inputs of said amplifier in accordance with the voltage level at the output thereof to prevent said amplifier from attaining a saturated mode.

12. The electrosurgical unit defined by claim **8,** wherein the output means includes a cut level control means and a coagulation level control means for individually controlling the gain of the push-pull amplifier to thereby control the amplitude of the output signal, said cut level control means and said coagulation control means being respectively operated in response to the application thereto of mode selection signals corresponding to cutting and coagulating signals, respectively.

13. The electrosurgical unit defined by claim **12,** further including monitoring means for disabling said electrosurgical unit in response to the detection of unequal amounts of current flowing to and from a patient with respect to said unit.

14. The electrosurgical unit defined by claim **12,** further including means for monitoring the temperature of said electrosurgical unit to disable said unit in response to said temperature thereof exceeding a selected temperature.

15. The electrosurgical unit defined by claim **14,** said drive means including:

a first multivibrator for providing pulses at a rate that is twice said selected frequency;

a bistable means having two states and producing output signals corresponding to each of two states thereof said bistable device being switched between said two states in response to said pulses from said first multivibrator; and

gating means connected to be responsive to said first multivibrator pulses and to the output signals of said bistable device for providing said drive pulses.

16. The electrosurgical unit defined by claim **15,** said second means including a second multivibrator connected to disable said bistable device for predetermined time periods at predetermined time intervals, said bistable device being prevented from providing said drive pulses to said gating means when disabled.

17. The electrosurgical unit defined by claim **16,** said third means including means for alternately permitting and preventing, in accordance with a predetermined timing sequence, said second multivibrator from disabling said bistable device for said predetermined time periods at said predetermined time intervals.

18. The electrosurgical unit defined by claim **17,** further including inductive coupling means for providing said drive pulses to said output means.

19. The electrosurgical unit defined by claim **1** further including actuator means for controlling the selection and generation of said cutting signals, coagulating signals, and blended signals in response to manual manipulation of said actuator means.

20. The electrosurgical unit defined by claim **19,** further including mode selection means for generating mode selection signals in response to operation of said actuator means, said mode selection signals being applied to control the operation of said first, second and third means to have selectively provided said cutting signals, coagulating signals, and said blended signals.

21. The electrosurgical unit defined by claim **1,** further including monitoring means for disabling said electrosurgical unit in response to the detection of unequal amounts of current flowing to and from a patient with respect to said unit.

22. The electrosurgical unit defined by claim **1,** further including means for controlling the output amplitude of said cutting signals and said coagulating signals.

23. The electrosurgical unit defined by claim **1** wherein the output means includes level control means for providing the independent adjustment of the amplitude level of the cutting and coagulating components of the blended signal.

24. The electrosurgical unit defined by claim **23** wherein the level control means includes means for manually adjusting said level control means.

25. The electrosurgical unit defined by claim **24** wherein said third means includes means to provide a blended signal in which the cutting component has a time duration of approximately three times the time duration of the coagulating component.

26. An electrosurgical unit for generating electrical signals to be applied to the body of a patient by an electrosurgical electrode for producing surgical cutting and coagulation, the electrosurgical unit comprising:

first means for generating a high frequency cutting signal for producing surgical cutting when applied to the body of a patient;

second means for generating a succession of bursts of a high frequency signal for providing a coagulating signal which produces coagulation when applied to the body of a patient;

a pair of output terminals adapted to be coupled to the electrosurgical electrode;

output means coupled between the first and second means and the output terminals for applying a blended signal to the output terminals, the blended signal consisting of successive intervals of the cutting signal and coagulating signal to alternately produce cutting and coagulation when applied to the body of a patient; and

level control means coupled to the output means for providing an independent adjustment of the amplitude level of the cutting and coagulating components of the blended signal.

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