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Chutjian et al.

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(45) **Date of Patent: Mar. 20, 2001**

(54) **POWER SUPPLY WITH AIR CORE TRANSFORMER AND SEPERATED POWER SUPPLIES FOR HIGH DYNAMIC RANGE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/392,351**

(22) Filed: **Sep. 8, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/099,630, filed on Sep. 8, 1998.

(51) **Int. Cl.**7 .... **H02M 7/155**

(52) **U.S. Cl.** **363/97**; 363/25; 363/134

(58) **Field of Search** 363/25, 26, 97, 363/98, 132, 16, 17, 133, 134

(56) **References Cited**

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5,510,974	*	4/1996	Gu et al.	363/134
5,590,033	*	12/1996	Kawano	363/25

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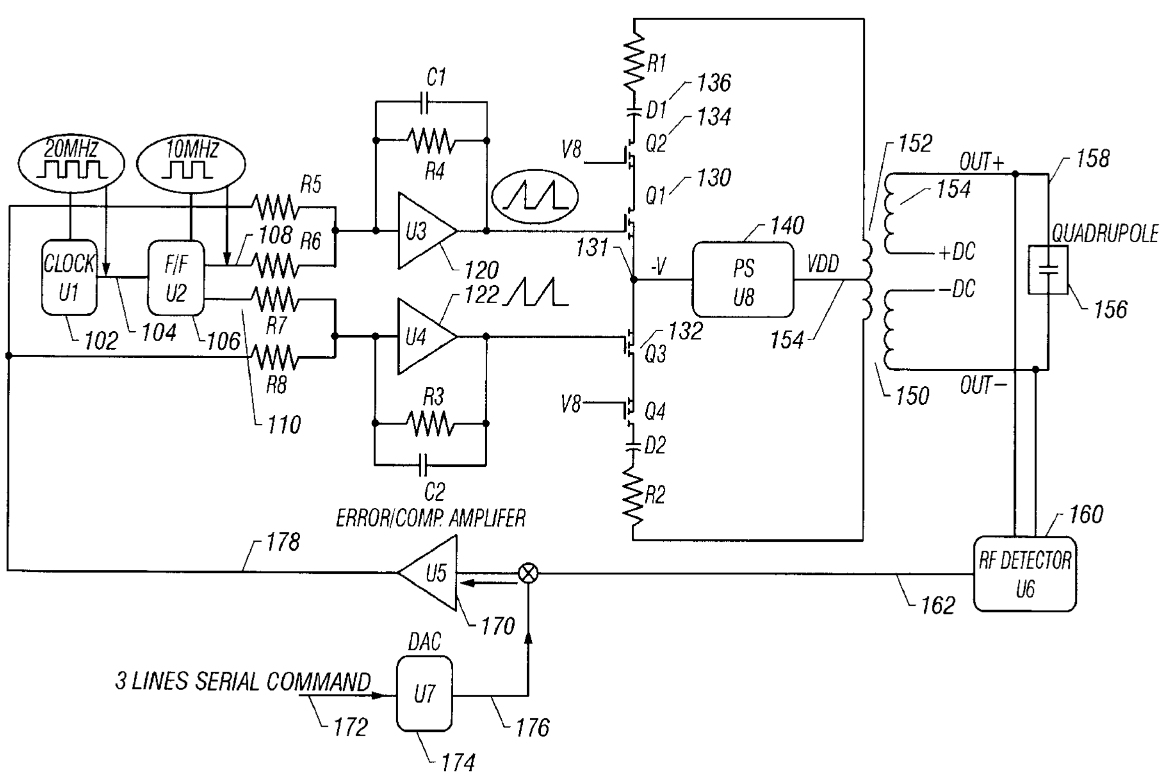
Primary Examiner—Adolf Deneke Berhane
(74) *Attorney, Agent, or Firm*—Fish & Richardson P.C.

(57) **ABSTRACT**

A power supply for a quadrupole mass spectrometer which operates using an RF signal. The RF signal is controllable via a feedback loop. The feedback loop is from the output, through a comparator, and compared to a digital signal. An air core transformer is used to minimize the weight. The air core transformer is driven via two out of phase sawtooth signals which drive opposite ends of the transformer.

6 Claims, 1 Drawing Sheet



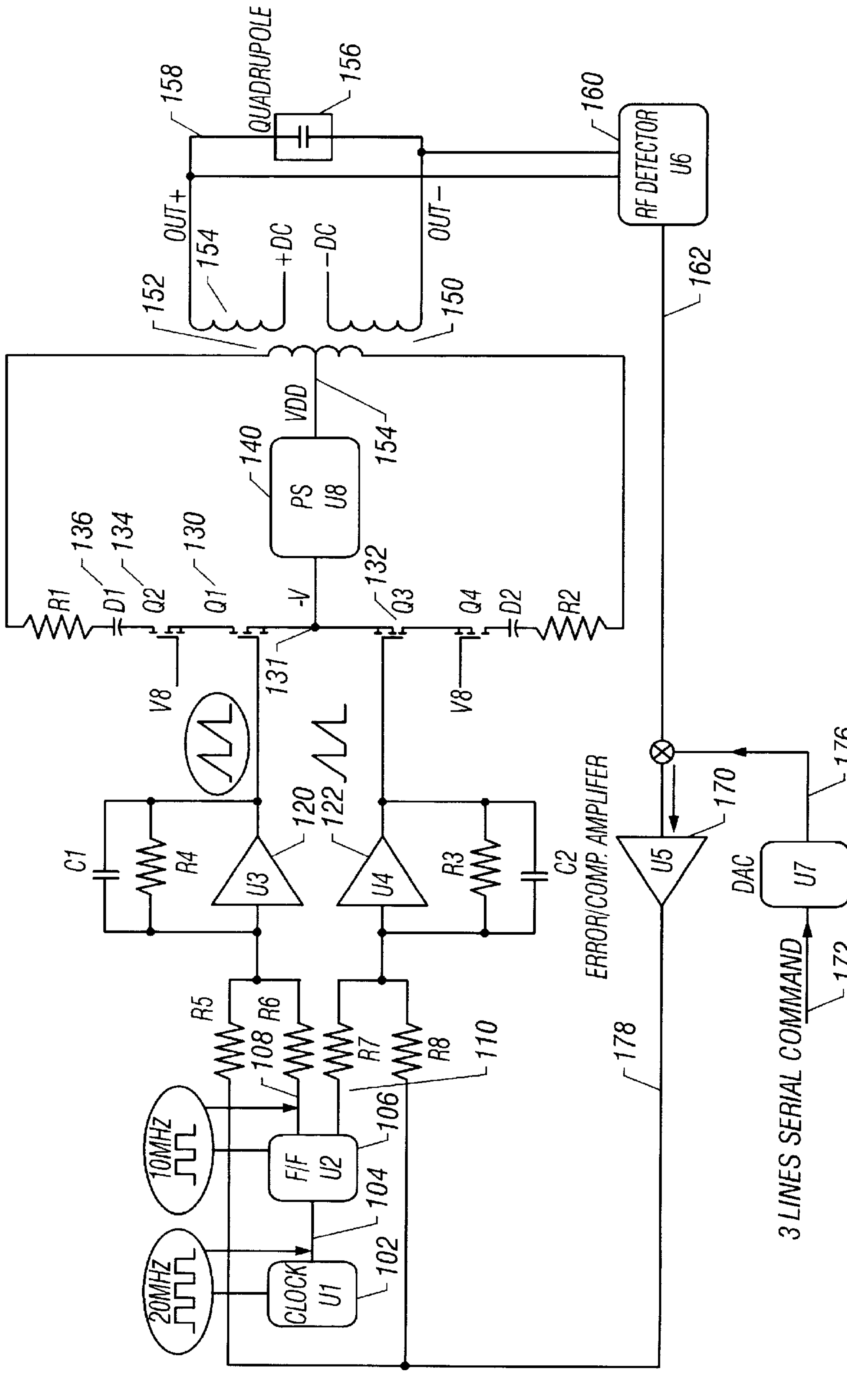

QUADRUPOLE
156
158
160
RF DETECTOR
U6
OUT+
OUT−
+DC
−DC
154
152
150
162
VDD
154
PS
U8
140
R1
D1
Q2
Q1
-V
Q3
Q4
D2
R2
136
134
130
132
131
V8
V8
C1
R4
U3
120
122
U4
R3
C2
ERROR/COMP. AMPLIFIER
U5
170
176
DAC
U7
174
3 LINES SERIAL COMMAND
172
178
R5
R6
R7
R8
108
110
106
104
102
10MHZ
20MHZ
F/F
U2
CLOCK
U1

FIG. 1

POWER SUPPLY WITH AIR CORE TRANSFORMER AND SEPERATED POWER SUPPLIES FOR HIGH DYNAMIC RANGE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/099,630, filed on Sep. 8, 1998.

STATEMENT AS TO FEDERALLY SPONSORED RESEARCH

The invention described herein was made in the performance of work under a NASA contract, and is subject to the provisions of Public Law 96-517 (35 U.S.C. 202) in which the Contractor has elected to retain title.

BACKGROUND

Certain applications, including a quadrupole mass spectrometer, can require a specialized power supply.

A power supply for this purpose has specialized requirements. It should be a high frequency power supply that has a variable peak RF amplitude, but is frequency and voltage stable once set. It should also be fully floating. These power supplies should also be capable of driving a primarily capacitive load.

If the device will be operating unattended or in space, the power supply should also be lightweight and efficient.

SUMMARY

The present disclosure teaches a stable, high amplitude, high frequency radio frequency and direct current power supply system. According to one aspect, the system uses a clocked operation to turn on power from a power supply.

A high dynamic range power supply is described that has an an oscillator assembly operating from a first power supply and produce first and second out-of-phase, gradually increasing, signals, first and second transistors, coupled to receive said first and second signals respectively, and turned on by the signals to produce an oscillating output. The first transistor produces a first part of the oscillating output and the second transistor produces a second part of the oscillating output. A a feedback loop has a detector sensing a level of the oscillating output and producing a signal indicative thereof. A second element compares that signal to a reference and produces an error output indicative of the difference, said error output causing a change in said first and second drive signals. The first transistor is referenced to a second power supply, having a different level than the first power supply.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a schematic of the system.

DETAILED DESCRIPTION

The system is shown in detail in FIG. **1**. A clock **102** produces a basic high frequency output **104**, here shown as a 20 megahertz clock. It should be understood that any other frequency could be used. A flip flop amplifier **106** divides the oscillating output **104** into two, out-of-phase 10 megahertz signals **108** and **110**. The in-phase 10 megahertz signal **108** is taken as a baseline (zero) phase shift, while the out-of-phase 10 MHZ signal **110** is shifted by 180 degrees relative to signal **108**.

The output signals **108** and **110** are provided into two analogous, but out-of-phase circuits.

The integrator/summing amplifier **120** is shown as an operational amplifier with a capacitor C**1** and resistor R**4** in its feedback loop. This effectively changes the square wave output **108** into a gradually increasing signal such as a sawtooth shape having a similar frequency to the driving signal. The sawtooth frequency is applied to the gate of MOSFET **130**, and periodically turns on the MOSFET **130**. When MOSFET **130** is turned on, it drives current from the power supply **140** to one end of the primary **152** of an air core transformer **150**. The return for the power supply **140** is coupled to the center tap **154** of the air core transformer **150**. Use of a air core transformer can reduce the weight of the system.

MOSFET **130** begins conducting when the sawtooth level reaches the threshold voltage (V_{th}) of the MOSFET **130**. As the level of the sawtooth increases at the gate of MOSFET **130**, the conduction angle increases. As MOSFET **130** turns on more completely, it conducts more current. The phase-shifted signal **110** is analogously coupled through an amplifier **122** to an analogous MOSFET **132**. The two circuits operate similarly, but 180 degrees out-of-phase. When MOSFET **130** is in its active phase, MOSFET **132** is off. Conversely, when MOSFET **132** is in its active phase, the MOSFET **130** is off. In this way, the primary **152** of transformer **150** is being alternatively pushed and pulled from opposite directions by two out-of-phase 10 MHZ signals. The output is therefore proportional to the amount of pushing and pulling that occurs.

The secondary **154** of transformer **150** is connected to a load **156** which can be a quadrupole mass spectrometer for example. If a quadrupole mass spectrometer is used, then the inductance of the air core transformer **150** can be adjusted to resonate with a capacitance of the analyzer. The inductance of **T1** can be adjusted either mechanically or by changing the windings ratio of the transformer. Use of an air core transformer reduces the weight, and makes it feasible to use such a device. A transformer-coupled output ensures floating output.

The secondary **154** output is also connected to an RF detector **160** which produces a detection signal **162** with a DC level that is proportional to the amplitude of the RF signal **158** produced at the secondary **154** of the transformer **150**. The RF detector can include, for example, a rectifying diode. The RF detection signal **162** is coupled to one input of an error amplifier **170**. The other input of the error amplifier **170** receives a command **176** indicative of the desired RF level. A serial input command **172** is connected to digital to analog converter **174** which is converted to an analog level **176** indicating the desired level. This analog level **176** is coupled to the second input of error amplifier **170**.

The error amplifier **170** produces an error output **178** indicating the difference between the commanded level **172** and the actual level. This difference is coupled through resistors R**8** and R**5** to the input node of the respective sawtooth amplifiers **120** and **122** where it sums with the flip-flop outputs **108**, **110**. When the error amplifier output **178** is high, it increases the oscillation signal to a higher level, thereby increasing the drive to the input of the amplifier **120**. This effectively produces more conduction from the transistor **130**, thereby increasing the amplitude of the RF signal. The increased-amplitude RF signal is reflected by an increase in the output **162** of the RF detector **160**, which hence lowers the error signal **178**.

This control loop provides extremely stable RF and DC voltages. Hence, this system can be used for long term unattended operation in a changing external environment, such as in space or under highly variable temperatures.

An important feature of this circuit is its ability to obtain a large dynamic range output signal. At low levels, the drive signal can couple through the gate of the MOSFET, and generate an output signal which is much greater than the desired minimum signal. In fact, the desired minimum signal for a quadrupole mass analyzer is about that necessary to separate one atomic mass unit. In order to avoid the coupling-through operation, a cascade stage MOSFET **134** is placed in series with a diode **136**. The MOSFET is biased to bias level VB. This provides the isolation ot avoid the punch through phenomena noted above.

Another problem is based on the characteristics of operational amplifiers that are commonly used for this system. Most operational amplifiers have peak voltages of about 3 to 4 volts for the sawtooth wave produced by the amplifiers. This level might not be high enough to bias the available MOSFETs to drive enough power at the output levels. The peak voltage of the sawtooth is hence increased, by referencing the return of the main power supply to a negative voltage at node **131**. By so doing, the peak value seen by the MOSFET is increased by the level of the negative voltage present at the return of the driving power source.

Other embodiments are within the disclosed system.

What is claimed is:

1. A high dynamic range power supply, comprising:

an oscillator assembly operating from a first power supply and produce first and second out-of-phase signals which have a gradually increasing portion;

first and second transistors, coupled to receive said first and second signals respectively, and turned on by said signals to produce an oscillating output, wherein said first transistor produces a first part of the oscillating output and said second transistor produces a second part of the oscillating output;

a feedback loop, including a detector sensing a level of the oscillating output and producing a signal indicative thereof, a second element comparing said signal to a reference and producing an error output indicative of the difference, said error output causing a change in said first and second drive signals;

wherein said first transistor is referenced to a second power supply, having a different level than said first power supply.

2. A supply as in claim **1** further comprising a transformer receiving said first and second parts at a primary thereof, said transformer having an air core.

3. A supply as in claim **2** further comprising a cascode stage, between said first transistor and said primary, said cascode stage including a cascode transistor and a diode.

4. A supply as in claim **1** wherein said clock includes a oscillation producing device and a dividing device that divides said oscillation producing device into two out of phase signals, both said clock and said dividing device operating from said first power supply.

5. An supply as in claim **1** wherein said second element includes an error amplifier, and a digital to analog converter, receiving a digital serial command at an input thereof, and producing an analog output at an output thereof, said analog output being compared with the signal from said detector.

6. A high dynamic range power supply, comprising:

an oscillator assembly operating from a first power supply and produce first and second out-of-phase sawtooth shaped signals;

first and second transistors, coupled to receive said first and second signals respectively, and turned on by a level of said signals increasing above a specified level, to produce an oscillating output, wherein said first transistor produces a first part of the oscillating output and said second transistor produces a second part of the oscillating output;

an air core transformer, having a primary driven at a first end by said first part, and driven at said second end by said second part; and

a feedback loop, including a detector sensing a level of the oscillating output and producing a signal indicative thereof, a second element comparing said signal to a reference and producing an error output indicative of the difference, said error output causing a change in said first and second drive signals;

wherein said first transistor is referenced to a second power supply, having a different level than said first power supply.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,205,043 B1
DATED : March 20, 2001
INVENTOR(S) : Ara Chutjian et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

The title page showing the illustrative figure should be replaced with the attached title page.

In the drawings replace the single drawing sheet.

Signed and Sealed this

Twenty-ninth Day of July, 2003

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

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Primary Examiner—Adolf Deneke Berhane
(74) *Attorney, Agent, or Firm*—Fish & Richardson P.C.

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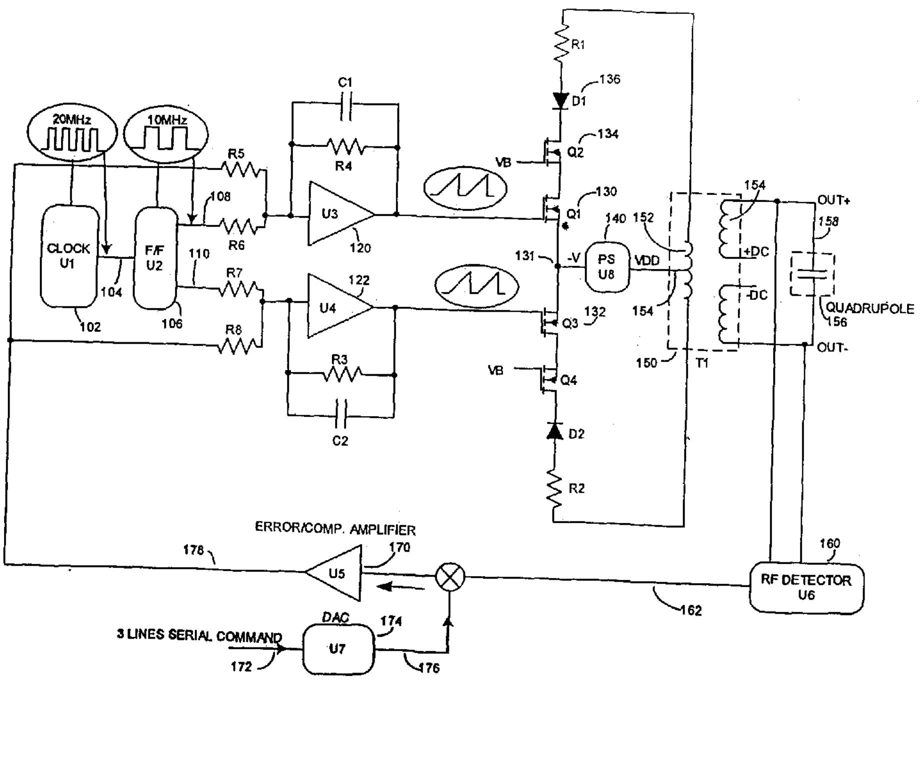

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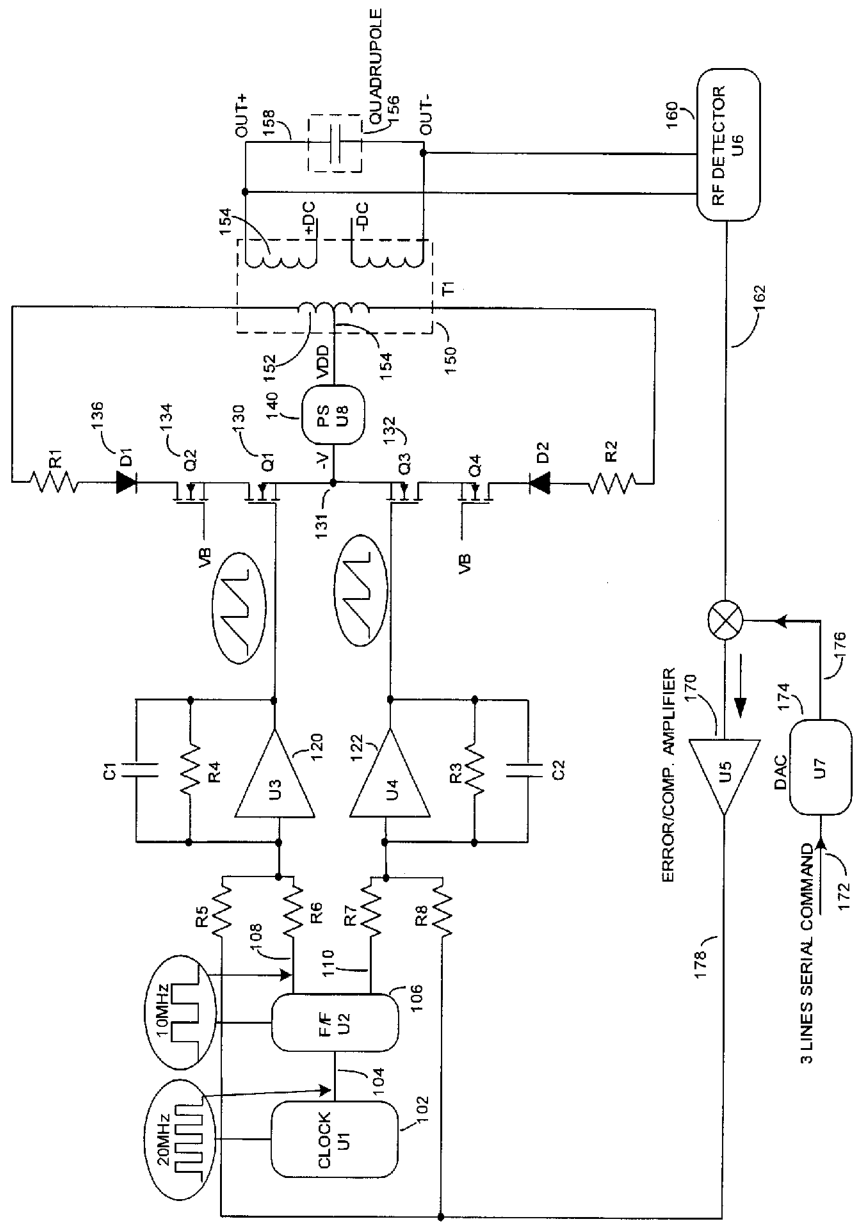

FIG. 1