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(54) **QUADRUPOLE MASS SPECTROMETER DRIVER WITH HIGHER SIGNAL LEVELS**

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

(51) **Int. Cl.**[7] **H01E 27/34**

(52) **U.S. Cl.** **336/181**; 250/292

(58) **Field of Search** 336/181; 250/292; 363/25, 97, 134

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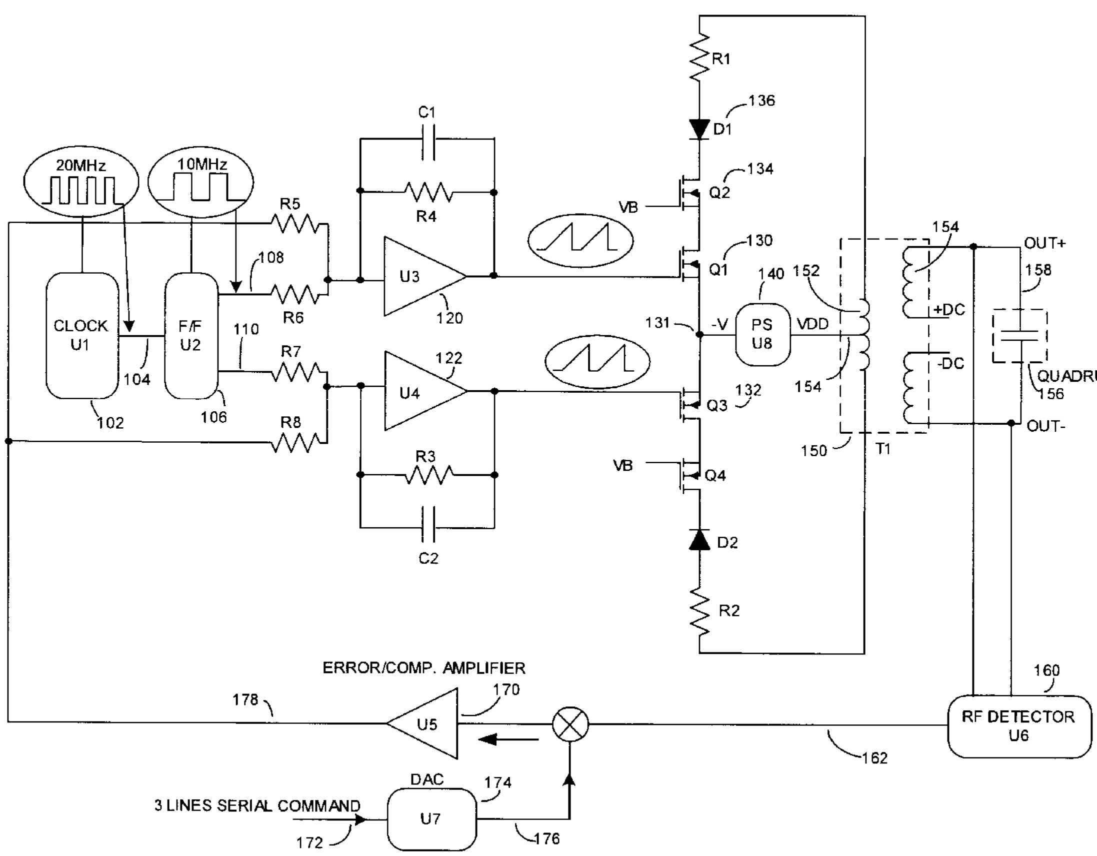
(57) **ABSTRACT**

Driving a quadrapole mass spectrometer includes obtaining an air core transformer with a primary and a secondary, matching the secondary to the mass spectrometer, and driving the primary based on first and second voltage levels. Driving of the primary is via an isolating stage that minimizes low level drive signal coupling.

3 Claims, 1 Drawing Sheet



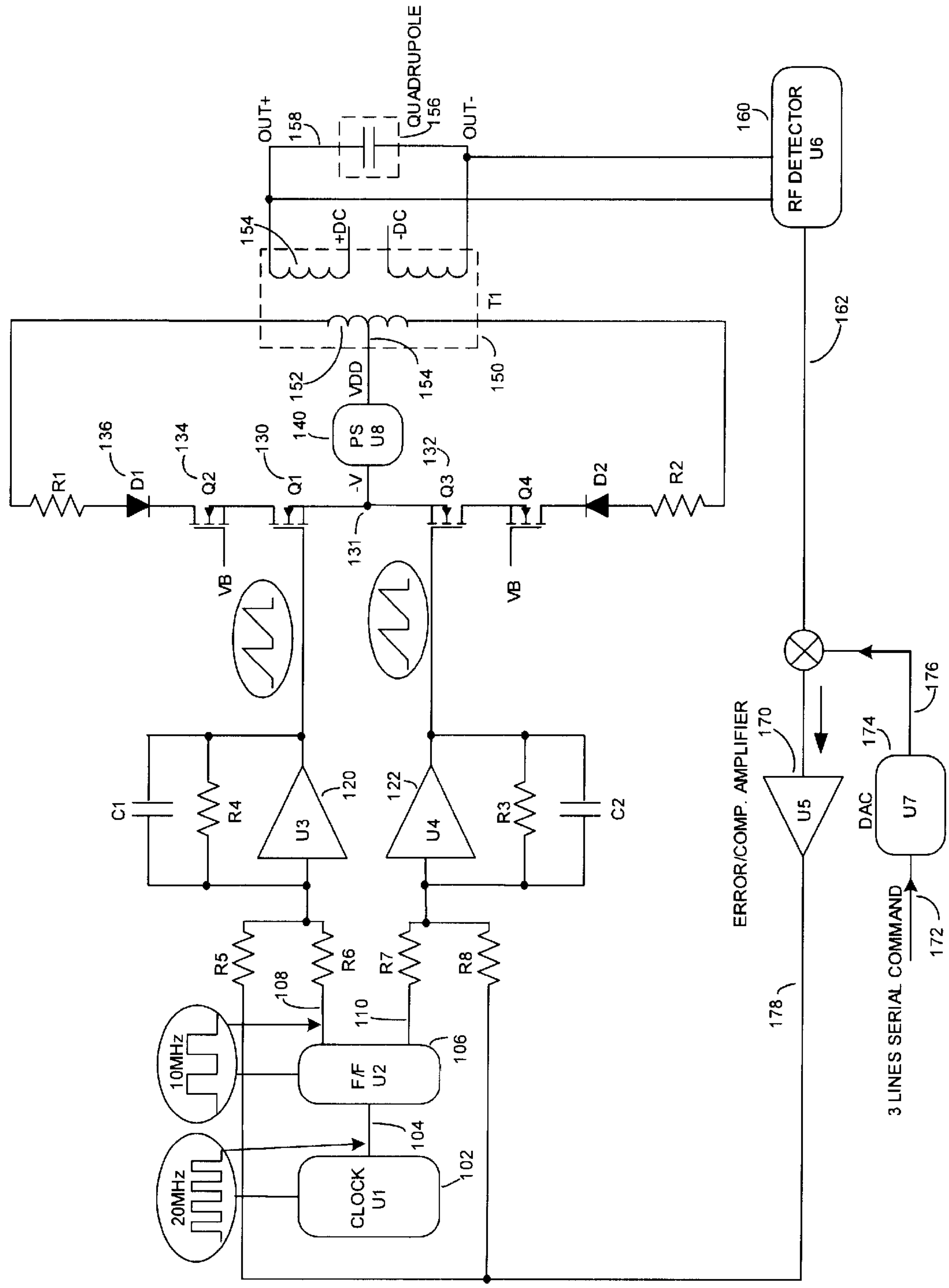

OUT+
158
QUADRUPOLE
156
OUT-
160
RF DETECTOR
U6
154
+DC
-DC
T1
152
VDD
154
150
162
R1
136
D1
134
Q2
130
Q1
140
PS
U8
-V
132
Q3
Q4
D2
R2
131
VB
VB
C1
R4
U3
120
122
U4
R3
C2
ERROR/COMP. AMPLIFIER
170
U5
174
176
DAC
U7
R5
R6
R7
R8
108
110
10MHz
F/F
U2
106
104
20MHz
CLOCK
U1
102
178
3 LINES SERIAL COMMAND
172

FIG. 1

QUADRUPOLE MASS SPECTROMETER DRIVER WITH HIGHER SIGNAL LEVELS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. application Ser. No. 09/813,654, filed Mar. 20, 2001 now U.S. Pat. No. 6,434,031 (allowed), which is a divisional of U.S. application Ser. No. 09/392,351, filed Sep. 8, 1999 (now U.S. Pat. No. 6,205,043), which 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 96-515 (35 U.S.C. 202) in which the Contractor has elected to retain title.

BACKGROUND

Certain applications, including a quadrapole 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 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 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 an air core transformer can reduce the weight of the system.

MOSFET **130** begins conducting when the sawtooth level reaches the threshold voltage (Vth) 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 quadrapole mass spectrometer for example. If a quadrapole 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 T**1** 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 quadrapole 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 to 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 method of driving an air core transformer having a primary and a secondary, the method comprising:

splitting a clock-generated output voltage signal into a plurality of out-of-phase voltage signals;

applying each of the out-of-phase voltage signals differentially to transistors to produce an oscillating signal, wherein each transistor shares a common junction node and, wherein a negative voltage is applied to the transistors at the common junction node to increase a peak value of the signals seen by the respective transistors between the gate terminal and the common junction node of the transistors; and

applying the oscillating signal to the primary.

2. The method of claim **1** wherein a first transistor produces a first part of the oscillating signal and a second transistor produces a second part of the oscillating signal, and wherein the first and second parts of the oscillating signal are applied to the primary of the transformer.

3. The method of claim **2** wherein applying a negative voltage to the transistors comprises referencing a return path for a power supply for the air core transformer to a negative voltage at the interconnecting junction node of the transistors, wherein the power supply is connected between the primary of the transformer and the junction node of the transistors.

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