United States Patent [19]

Bumgardner

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[54] **HIGH DYNAMIC RANGE VOLTAGE REGULATOR**

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy,** Washington, D.C.

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[52] **U.S. Cl.** ..... **323/22 T,** 323/38

[51] **Int. Cl.** **G05f 1/56**

[58] **Field of Search**..... 323/9, 22 T, 38; 307/297

[56] **References Cited**

UNITED STATES PATENTS

2,832,035	4/1958	Bruck et al.	323/22 T
2,976,475	3/1961	Dodge	323/22 T
3,207,973	9/1965	Smith	307/297
3,386,030	5/1968	Kann	323/22 T
3,548,294	12/1970	Houghton	323/22 T

OTHER PUBLICATIONS

(S0169 0129) Agapou et al., "A Transistorized Compensation Voltage Stabilizer—," Telecommunications, Vol. 23, No. 7, pp. 42–46, 1969.

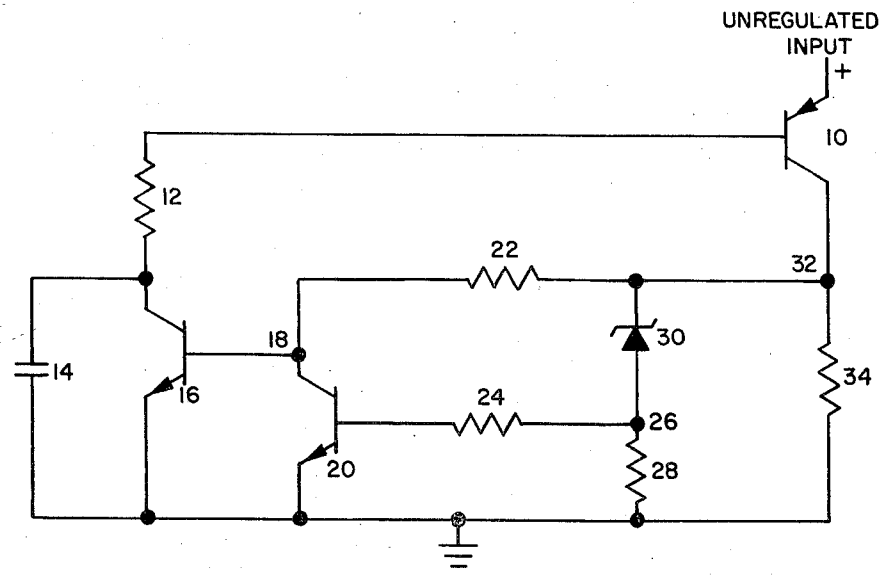
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[57] **ABSTRACT**

A highly efficient, high dynamic range voltage regulator wherein regulation is maintained even when the voltage differential between the output and the unregulated input becomes small.

3 Claims, 2 Drawing Figures



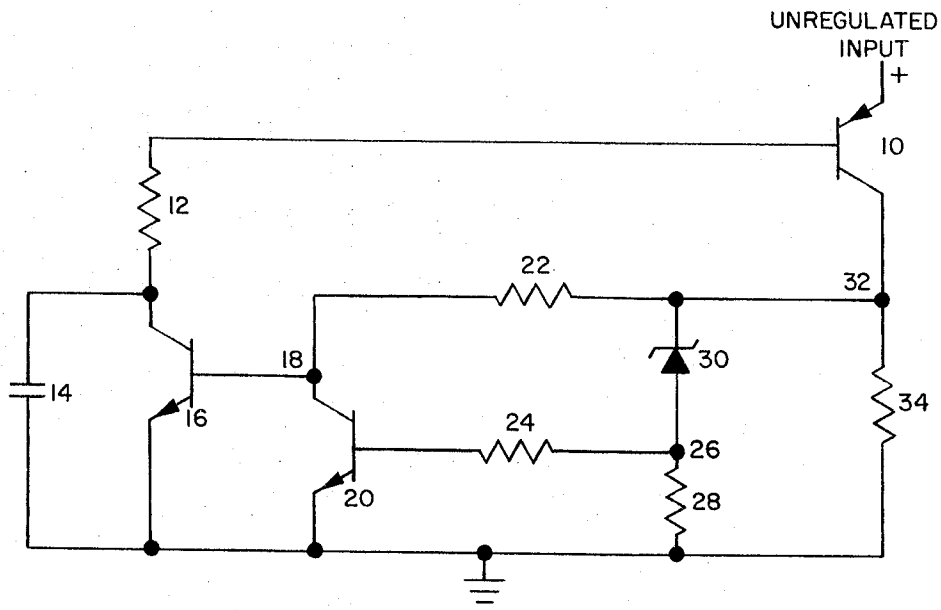

UNREGULATED
INPUT
+
10
12
22
32
18
30
14
16
34
24
26
20
28

Fig. 1

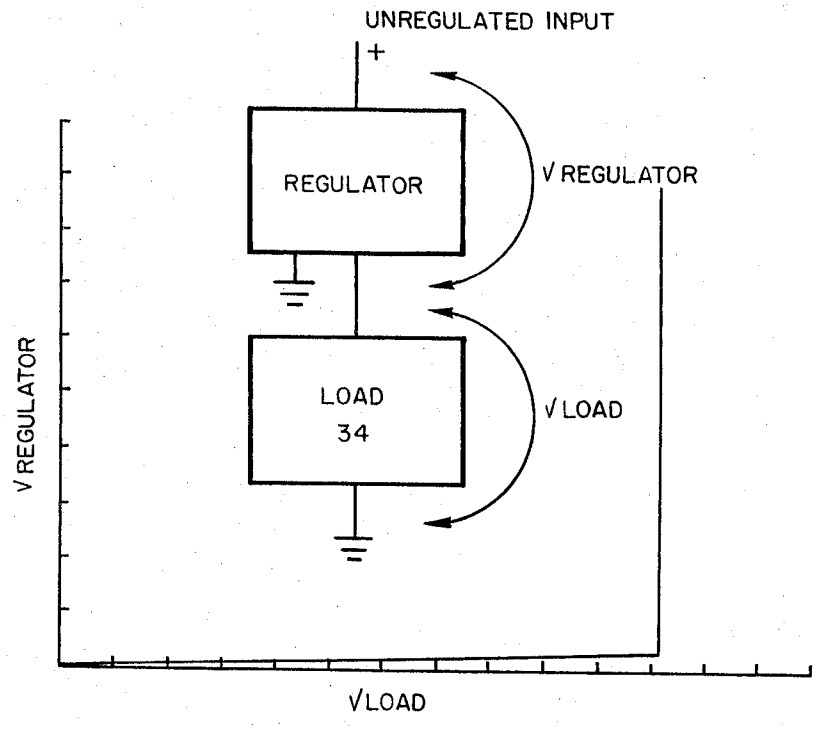

UNREGULATED INPUT
+
REGULATOR
V REGULATOR
LOAD
34
V LOAD
V REGULATOR
V LOAD

Fig. 2

HIGH DYNAMIC RANGE VOLTAGE REGULATOR

BACKGROUND OF THE INVENTION

In the field of electronics, voltage regulators are used extensively. Most prior devices utilize a transistor having its collector coupled to the unregulated input, its base coupled through a zener diode to ground, and its emitter coupled through the lead resistance to ground. A biasing resistance is used to couple the voltage source to the base.

As described, the old methods used a dropping resistor in series with the base of a transistor together with a zener reference. This approach requires at least 0.6 volts of voltage drop across the base-emitter junction to forward bias the transistor. As the supply voltage is increased in voltage, and as the minimum input voltage gets nearer to the desired output voltage, the biasing resistance becomes smaller and smaller for proper circuit operation. Unfortunately, as the bias and resistance becomes smaller, overall circuit efficiency is drastically lowered to the point where this type of circuit becomes unusable unless several volts are continuously being dropped across the regulator.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of the preferred embodiment of the present invention; and

FIG. **2** is a graph demonstrating the response of the preferred embodiment of the present invention, and includes a block diagram to define the source of the voltage measurements employed in the graph.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the present invention is shown in FIG. **1.** The unregulated input is coupled to the emitter terminal of transistor **10** which is the regulating transistor, regulating the output of the circuit. Once transistor **10** is chosen the maximum DC base current (I_B max) necessary to turn on the transistor is calculated for the required load current. The worst case situation should be used for the maximum saturation voltage values at the maximum load current.

Resistor **12** couples the base of transistor **10** to the collector of transistor **16** which, with related circuitry, regulates the conductivity rate of regulating transistor **10.** Resistor **12** may be a standard value that comes nearest to satisfying $F(12) \leq (V_{min} - 2)/I_B\text{max}$ of transistor **10.** The exact value may be calculated by dividing the minimum unregulated input voltage, minus the DC base to emitter voltage of transistor **10** for maximum current and the saturation voltage of transistor **16** where the DC collector current equals the maximum DC base current of transistor **10,** by the maximum DC base current of transistor **10.**

The base of transistor **16** is coupled through junction **18** and resistor **22** to the collector of transistor **10.** Resistor **22** may be the nearest standard value that satisfies $R(22) \leq \beta R(12)$, where β is the short-circuit gain of transistor **16,** i.e., where the DC collector current of transistor **16** is equal to the maximum DC base current of transistor **10.**

Zener diode **30** is coupled between junctions **26** and **32** (the collector of transistor **10**). Junction **26** is coupled to the base of transistor **20** through resistor **24.** With related circuitry, transistor **20** senses the value of the regulated output and provides an error adjusting output to transistor **16.** Resistor **28** is coupled between junction **26** and the circuit common ground. The collector of transistor **20** is coupled to the base of transistor **16,** and the emitter of transistor **20** is coupled to the circuit common ground. Diode **30** and resistor **28** should be chosen such that at the desired output voltage across resistor **34,** the voltage drop across diode **30** is just sufficient to cause transistor **20** to conduct.

Resistance **24** is in the feedback loop and is used to stabilize the loop. The smaller resistor **24** is, the less the output voltage will vary when the voltage input (or unregulated input) or the load resistance is varied. However, the larger resistance **24** is, the more stable will be the regulator. Therefore, the selection of resistor **24** involves a compromise. Capacitor **14** should be chosen to give the complete system stability. This can be accomplished by establishing the product $1/R(12)C(14)$ at a value lower than the oscillation frequency of the circuit, such that the oscillations will be damped should oscillation occur.

If the input is a slowly rising signal, a momentary switch might be required to initiate the circuit. This is because sufficient current might not be available to trigger transistor **16** and thereby, place transistor **10** in the conductive mode. The momentary switch may be placed between transistor **10** and the input, and would allow the signal to attain a value sufficient to initiate the circuit before the input is applied.

Two of the more significant approaches utilized in the present invention should be mentioned. The first is to invert the regulator transistor of the prior devices. This permits the base drive requirements to come from ground potential, resulting in a maximum regulator voltage drop that is not greater than the collector to emitter saturation voltage. The second significant approach is to obtain all regular transistor base drives from ground potential. This allows the output voltage, or regulated output, to come within 0.1 volts of the input voltage, or unregulated input. It is contemplated that either dissipation or chopper regulation may be used to take advantage of this configuration.

FIG. **2** is a graph showing the representative response of the present invention. As can be easily seen, the load voltage is maintained in a nominally constant value as the unregulated voltage varies. The unregulated voltage equals the voltage drop across the load (V Load) plus the voltage drop across the regulator circuit (V Regulator). The constant load voltage is maintained until the unregulated voltage becomes very nearly equal to the value of the load voltage which the circuit is designed to maintain at a regulated level. Thereafter, if the unregulated voltage is reduced regulation cannot be maintained. If the unregulated input drops further to a value below that of the designed load voltage, the load voltage will rapidly deteriorate as shown by the nearly horizontal line. The graph shows that the present invention will maintain the load voltage at its design value even though the unregulated input might be at a level that is only slightly greater than the design load voltage.

Basically, the operation of the preferred embodiment of the present invention is as follows: The unregulated is inputted to regulating transistor **10.** The regulated output is taken across resistor **34,** i.e., between junction **32** and the circuit common ground. Transistor **20** becomes conductive when the output exceeds its desired

regulated value. As a result, transistor **20** and its associated components operate to regulate the maximum output voltage of the circuit. Transistor **16** and its associated components are used to control the current flow through regulating transistor **10.** The base of transistor **16** is shown as coupled through junction **18** and resistor **22** to junction **32,** or the collector of transistor **10.** Resistor **22** can be coupled directly to the unregulated input if desired, but the results of such a modification are less effective to achieve the results described than the interconnection shown in FIG. **1** of the preferred embodiment, i.e., regulation is not as tight.

The following components are listed by number as representative of the respective components in FIG. **1** used in an operative embodiment of the present invention. The components are offered as merely exemplary of an operational embodiment.

SYMBOL	COMPONENT	TYPE OR VALUE
10	Transistor	2N3792
12	Resistor	100 ohm
14	Capacitor	1 microfarad
16	Transistor	2M2219A
20	Transistor	2M2219A
22	Transistor	10 Kohm
24	Resistor	1 Kohm
28	Resistor	2 Kohm
30	Zener Diode	2N5245
34	Load Resistor	Selectable (20 ohm)

A couple of the advantages of the present invention are that the only voltage drop in series with the load and the unregulated input is the forward drop across transistor **10.** The drop can be quite small if desired and is limited only by the collector to emitter saturation voltage and the maximum allowable base current of transistor **10.** As a result, it is a further advantage of the circuit that the output may be reliably operated at voltages within a fraction of the minimum supply voltage, and yet maintain full regulation.

It should be noted that if a steeper input voltage/load voltage curve is required, a Darlington can be substituted for transistor **16.** Also, if vernier voltage adjustments are desired a potentiometer can be substituted for resistor **28** by coupling resistor **24** to the movable contact element of the potentiometer.

I claim:

1. An electronic voltage regulator for providing a regulated output voltage from an unregulated input, comprising:

a regulating transistor coupled to said unregulated input;

circuit means coupled to the base terminal of said regulating transistor for controlling the conductivity rate of said regulating transistor in response to the value of the regulators output; and

circuit means coupled to said rate controlling means for sensing the value of the regulator's output and providing an output to said rate controlling means in response thereto;

wherein said rate controlling means includes a transistor having the collector coupled to the base of said regulating transistor, said sensing and providing means is coupled to the base of the said transistor of the rate controlling means, and the collector of said regulating transistor is directly connected to the output terminal of the regulator, and

said sensing and providing means includes a transistor having its collector coupled to the base of the said transistor of the rate controlling means, and a diode coupled between the regulator's output terminal and the base of the said transistor of the sensing and providing means; and

wherein a resistor couples the collector of the said transistor of said rate controlling means to the base of said regulating transistor, and a capacitor is directly coupled between the collector and the emitter of the said transistor of the rate controlling means.

2. The regulator of claim **1** wherein a resistor is directly coupled between the said output terminal and the base of the said transistor of the rate controlling means.

3. The regulator of claim **2** wherein said diode is connected through a resistor to the base of the said transistor of the sensing and providing means, and a resistor couples the junction between the diode and the resistor to the emitters of both the said transistor of the rate controlling means and the said transistor of the sensing and providing means.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,873,907

DATED : 25 March 1975

INVENTOR(S) : JON HUNT BUMGARDNER

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

On the Cover,

[73] Assignee: The United States of America as represented by the Secretary of the Navy, Washington, D. C.

is deleted.

Column 3, lines 23 and 24 that portion of the tabulation reading 2M2219A (two occurrences) should be 2N2219A; line 28, that portion of the tabulation reading 2N5245 should be 1N5245.

Signed and Sealed this

twenty-second Day of June 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

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