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NEW TYPE OF DC VOLTAGE REGULATOR USING OPTICAL FIBER AS SENSE LINE

HIROAKI IKEDA, JINZHU LI, MASATOSHI MIYASHITA,
HIROFUMI YOSHIDA, MINORU ANDOU, SHIGENOBU SHINOHARA
ETSUO TSUCHIYA*, AND KEN-ICHI NISHIMURA*

Department of Electronic Engineering, Shizuoka University,
Hamamatsu JAPAN
* PALCOM ELECTRONICS CORPORATION, Hamamatsu JAPAN

ABSTRACT: Described is a DC voltage regulator of new type where an optical fiber is used as a sense line to transmit the PFM signal, which represents the load voltage and its change, from the load to the controller so as to make the equivalent sense-line length short. The prototype version provides a load voltage change rate of 2.3 % over the current range of 0 A to 5 A at 15 V DC, with an output impedance of 0.06 ohm.

1. INTRODUCTION

Although a series power regulator has been used to regulate a DC voltage at the load, the load voltage sometimes vibrates unexpectedly due to unstable operation of a feedback loop established by the controller, DC power feeder, load, and sense line when the load is arranged in a distant location far from the controller. The controller is in many cases located distant from the load since the DC voltage regulator is bulky compared with other electronic circuits mounted on PC boards, and both the DC power feeder and sense line are rather long.

The sense line is usually thin in diameter, having high inductance and high resistance causing inferior phase response. However, it is used to send the load voltage change back to the voltage comparator in the controller to compare the load voltage with the reference which may be program-controlled or unchanged at a fixed voltage in detecting an error voltage. Hence, unexpected changes or vibration may occur in the load voltage due to inferior phase response of the sense line. If an optical fiber is used in place of the wire sense line, the phase response may be improved and the voltage drop along the sense line may be reduced.

2. DC POWER REGULATOR CONFIGURATION

Figure 1 shows the schematic diagram of the DC power regulator of new type. The load voltage is set at 15 V DC and is sensed by using an operational amplifier and the operational amplifier output is then fed to the VCO whose pulse frequency corresponds to the load voltage.

Figure 2 shows the circuit diagram of the DC power regulator of new type.

The VCO output consists of a series of pulse FM (PFM) signals and is converted, by using an optical transmitter, into the corresponding optical pulse whose repetition rate is set at the VCO frequency. The frequency of the VCO is set at as high as 1 MHz so as to respond to rapid voltage change. The frequency of the VCO usually drifts

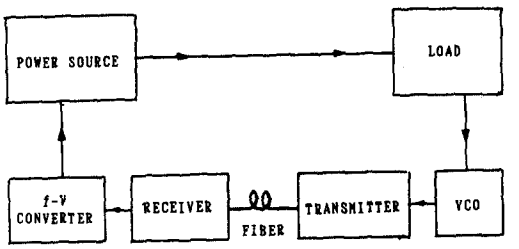

Fig.1 Schematic diagram of the DC power regulator.

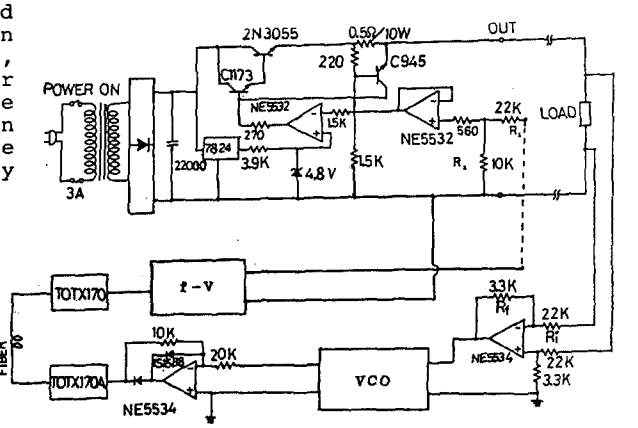

Fig.2 Circuit diagram of the DC power regulator.

with time and also changes with changing ambient temperature. By properly selecting the components and devices, the frequency of the VCO is however kept within a certain range which defines the DC voltage stability.

The optical transmitter sends the light pulses from an LED at 650 nm. The optical transmitter output is sent to an optical receiver via an optical fiber. The optical fiber is made of plastic material. The optical fiber senses no radio frequency interference signal unlike the wire sense line.

The optical receiver converts the optical pulse into the PFM signal and its output is fed to an f-v converter so as to set the load voltage at the specified value defined by reference. The f-v converter output is then fed to the error voltage amplifier in the controller so as to set the load voltage at the specified value. The reference voltage was specified unchanged in the prototype.

Since the optical fiber sends the optical PFM signal from the optical transmitter to the optical receiver, such troubles as optical power losses along the optical path cannot occur in this new type of DC power regulator if the optical power is much greater than the threshold intensity.

3. KEY ELEMENTS

3-1 VCO

Figure 3 shows the circuit diagram of the VCO for defining the load voltage. The main oscillator consists of 3 operational amplifiers and the temperature-coefficient-of-frequency(TCF) compensation circuit consists of a p-channel MOS-FET and bipolar transistors.

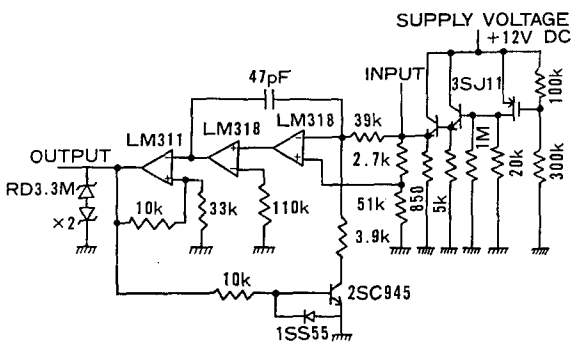

Fig.3 Circuit diagram of the VCO.

The frequency variation with changing temperature in the 30 to 95°C range are shown in Figure 4(a). Figure 4(b) shows the frequency variation with changing temperature unless the TCF compensation circuit is installed.

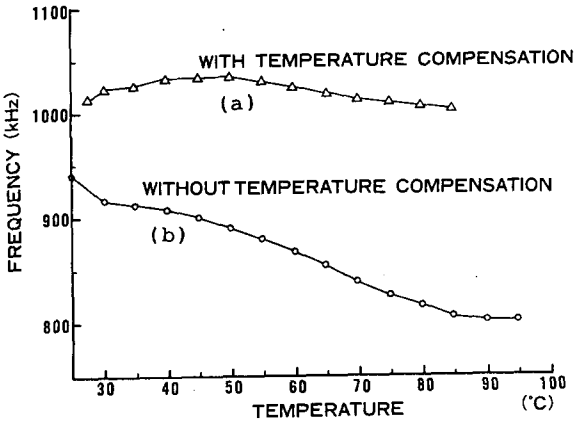

Fig.4 Frequency variation with temperature for the VCO.

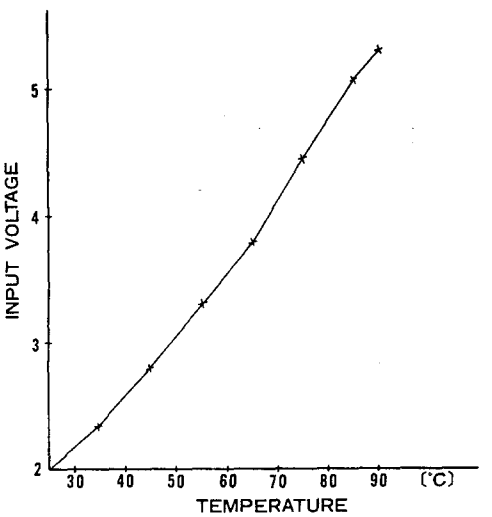

Fig.5 Temperature-to-input voltage relation of the main oscillator in the VCO.

The temperature-to-input voltage relation of the main oscillator, which is to be compensated by using the TCF compensation circuit, is shown in Figure 5.

The VCO output frequency at approximately 1 MHz defines the load voltage and a signal voltage defining both the load voltage and its change is fed to the VCO from operational amplifier NE5534 in Figure 2 for sensing the voltage across the load. Figure 6 shows the voltage-to-frequency relation of the VCO, measured at an ambient temperature of 24°C.

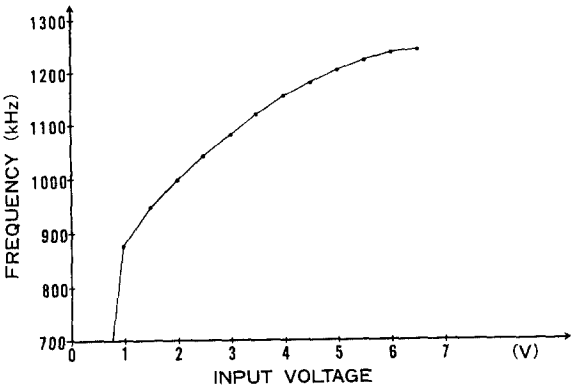

Fig.6 Voltage-to-frequency relation of the VCO.

3-2 F-v Converter

The f-v converter detects the VCO output frequency and its change.

The f-v converter consists of a chopper with an integrator and a PLL frequency change-to-voltage change (PLL f-v) converter. The chopper with an integrator has a response over the DC to 100 Hz range, and the PLL f-v converter has a response at any voltage change with no response at unchanged voltage. Thus, these outputs are combined together by using a summing circuit shown in Figure 7.

Figure 8 shows the circuit diagram of the PLL f-v converter. The PLL f-v converter, consisting of a PLL IC and peripheral components, has a sufficient frequency performance enough to respond to an abrupt voltage/current change at the load.

3-3 Optical Transmitter-Receiver Link

An optical transmitter consisting of an LED was used to generate the optical pulse at 0.65 um and a plastic fiber was used to send the optical pulse from the optical transmitter to optical receiver. Since the load voltage and its change are specified by the PFM signal in the VCO, the optical fiber type and length do not affect the error voltage even if the plastic fiber is of up to 100 meters.

4. PERFORMANCE

The load voltage was specified as 15 volts DC at up to 5.5 A in the prototype and an analog voltage controller was used to set the load voltage. Figure 9 shows the voltage-current curve for the load. The load voltage change rate was 2.3 % over the current range of 0 A to 5 A at 15 V DC. The output impedance was 0.06 ohm.

The VCO output frequency stability was also checked to confirm the short-term stability of the DC voltage regulator. Figure 10 shows the short-term stability of the VCO frequency for 4 hours at a room temperature of 20 C.

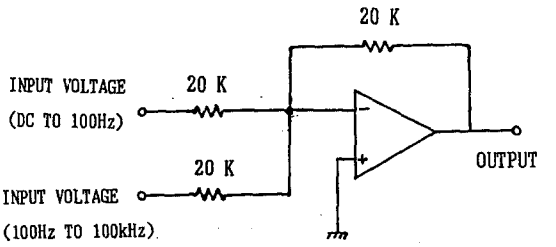

Fig.7 Circuit diagram of the summing circuit.

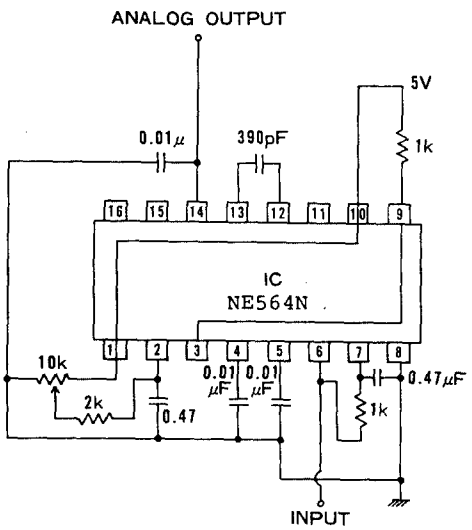

Fig.8 Frequency-to-voltage relation of the chopper with an integrator.

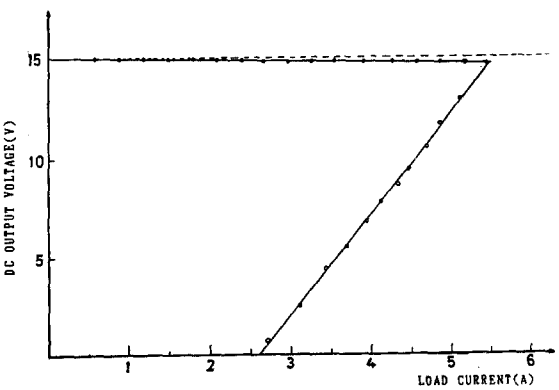

Fig.9 Voltage-current curve for the load.

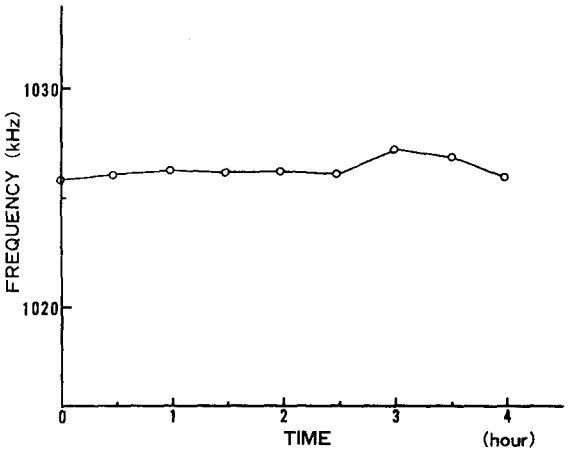

Fig.10 Short-term stability for 4 hours.

Ripples in the load voltage was 8 mV_{p-p} at a load current of 5 A and spikes due to the VCO output pulse was 5 mV_{p-p}.

The frequency response of the load voltage with respect to the load current change was flat at up to 10 kHz since the f-v converter was operated at higher clock rate. Figure 11 shows the transient response to the square-wave signal for the link established by the VCO and PLL f-v converter.

5. CONCLUSION

A new type of DC voltage regulator at 15 V DC, 5.5 A, which is suitable for remote control of the load voltage has been presented and its performance has been confirmed to be practical.

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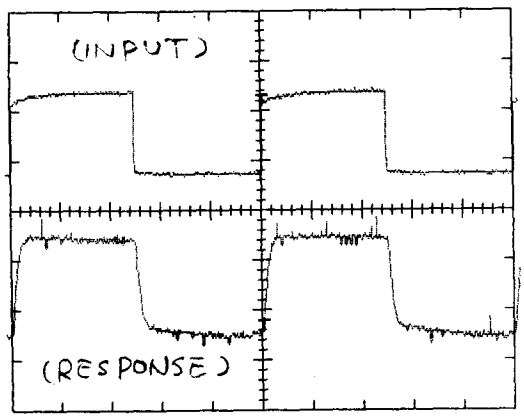
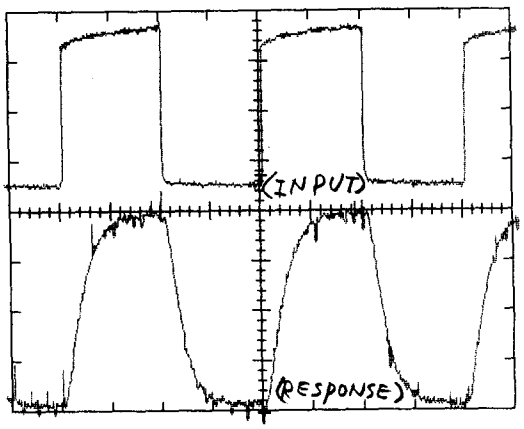


(a) 1 kHz



(b) 5 kHz

Fig.11 Transient response of the PLL f-v converter.