AN-292 Applications of the LM3524 Pulse-Width-Modulator

ABSTRACT

The LM3524 regulating pulse-width-modulator (PWM) is commonly used as the control element in switching regulator power supplies. This is in keeping with its intended purpose. Engineers closely associate this part with switching power supplies. Nevertheless, the flexible combination of elements (see box) within the LM3524 also allows it to be used in a number of other applications outside the power supply area. Because the device is inexpensive and operates off a single-sided supply, it can considerably reduce component count and circuit complexity in almost any application. The constant light intensity servo of Figure 1 furnishes a good example.

Contents

List of Figures

1   Constant Light Intensity Servo

The circuit of Figure 1 uses a photodiode's output to control the intensity of a small light bulb. The constant intensity output of the light bulb is useful in a number of areas, including opto-electronic component evaluation and quality control of photographic film during manufacture. In this circuit, the photodiode pulls a current out of the LF356 summing junction, which is directly related to the amount of light that falls on the photodiode's surface. The LF356 output swings positive to maintain the summing junction at zero and represents the photodiode current in amplified voltage form.

This potential is compared at the LM3524 to the voltage coming from the 2.5k "intensity" potentiometer wiper. A stable voltage for the "intensity" control is taken from the LM3524's internal 5-V regulator. The difference between the LF356 output and the "intensity" potentiometer output is amplified at a gain of about 70 dB, which is set by the 1 MΩ value at pin 9. The LM3524 output transistors are paralleled and provide drive to the 2N2219 switch transistor. The 5.6k and .01 µF values set the switching frequency at about 30 kHz. Because the LM3524 forms a switched mode feedback loop around the light bulb and photodiode, the average power delivered to the light bulb will be controlled by the photodiode output, which is directly proportional to the lamp's output. Frequency compensation for this feedback loop is provided by the .001 µF capacitor, which rolls off the loop gain at a 1 ms time constant.

Figure 2 shows the wave forms in the circuit. Trace A is the 2N2219 collector and trace B is the AC-coupled LF356 output. Each time the 2N2219 collector goes low, power is driven into the lamp. This is reflected in the positive going ramp at the LF356's output. When the 2N2219 goes off, the lamp cools. This is shown in the negative going relatively slow ramp in trace B. It is interesting to note that this indicates the bulb is willing to accept energy more quickly than it will give it up. Figure 3 elaborates on this. Here, trace A is the output of a pulse generator applied to the "step test" input and trace B is the AC-coupled LF356 output. When the pulse generator is high, the diode blocks its output, but when it goes low, current is drawn away from the "intensity" control wiper through the 22k resistor. This forces the servo to control bulb intensity at a lower value. This photo shows that the bulb servos to a higher output almost three times as fast as it takes to go to the lower output state, because the bulb more readily accepts energy than it gives it up. Surprisingly, at high intensity levels, the situation reverses because the increased incandescent state of the bulb makes it a relatively efficient radiator (Figure 4).
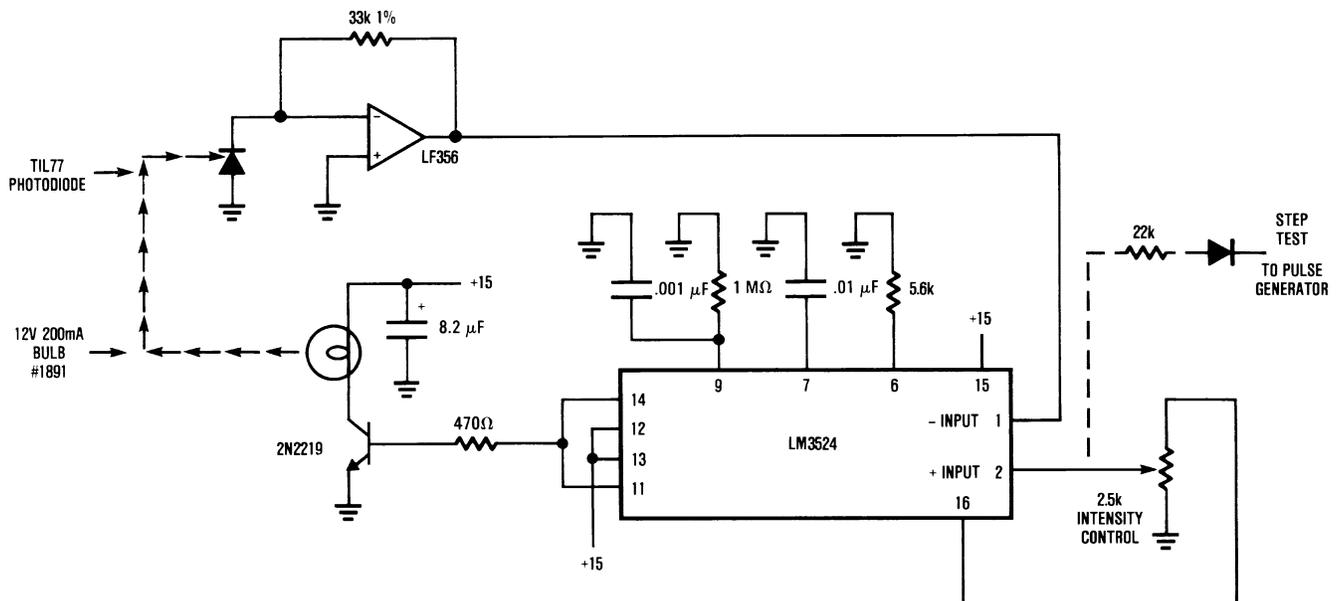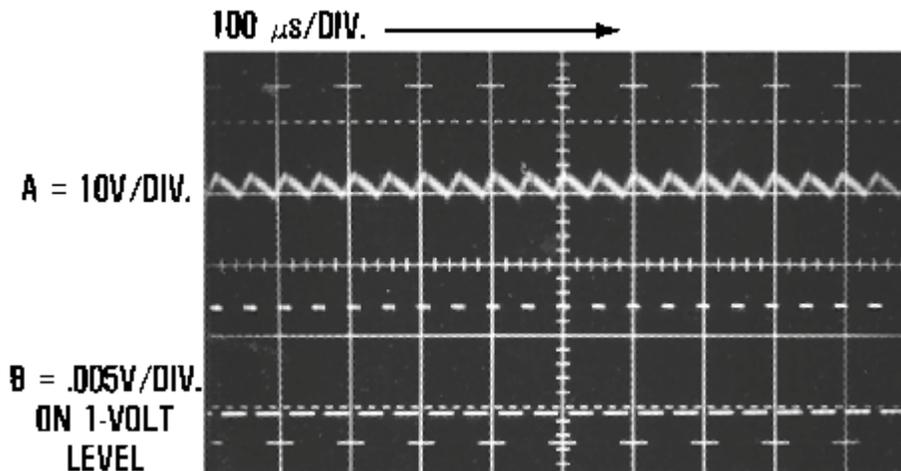

Figure 1. Constant Light Intensity Servo Circuit
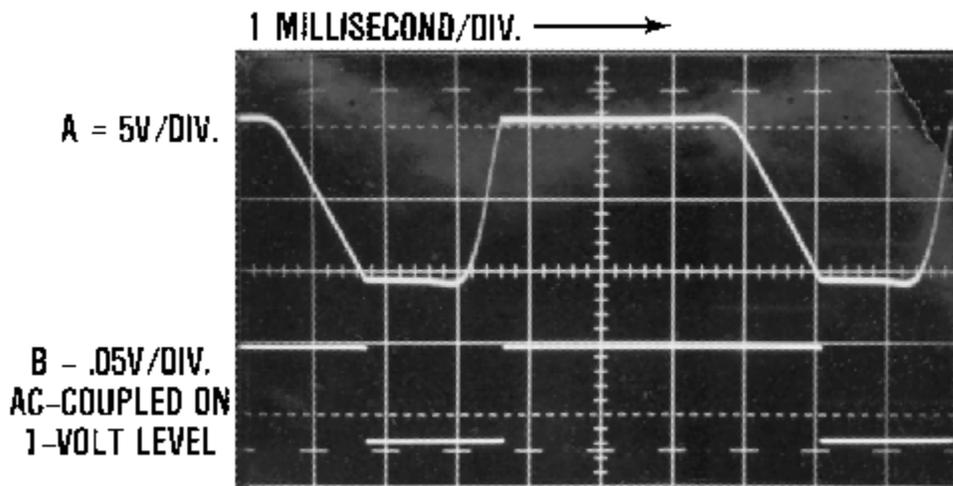
Figure 2. Constant Light Intensity Servo Waveforms

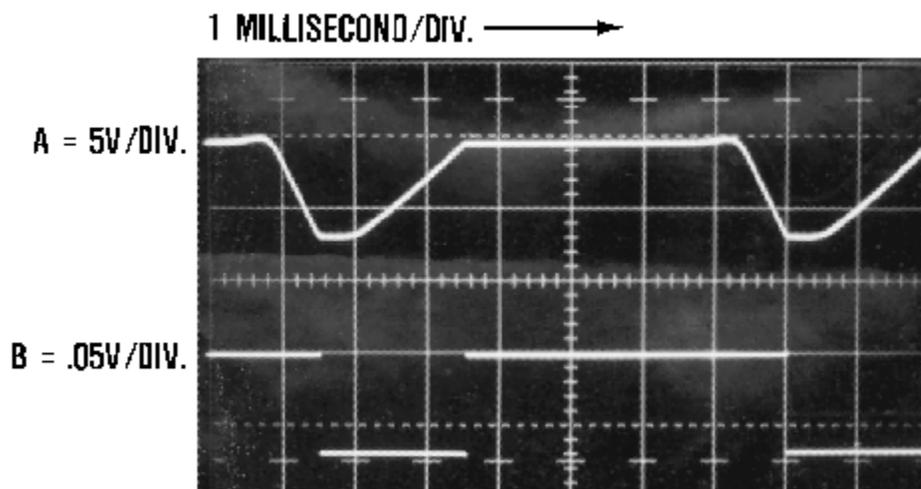**Figure 3. Constant Light Intensity Servo Waveforms**

Figure 4. Constant Light Intensity Servo Waveforms

2   Temperature-to-Pulse-Width Converter

The circuit in Figure 5 uses the LM3524 to convert the output of an LM135 temperature transducer into a pulse width that can be measured by a digital system, such as a microprocessor-controlled data acquisition system. Although this example uses the temperature transducer as the input, the circuit will convert any 0.1 to 5 V input applied to the 100 kΩ resistor into a 0–500 ms output pulse width with 0.1% linearity. In this circuit, the LM135's temperature-dependent output (10 mV/°K) is divided down and applied to A1's positive input. This moves A1's output high, driving the input to the LM3524's pulse-width modulation circuitry. The LM3524 pulse-width output is clipped by the LM185 reference and integrated by the 1 MΩ-0.1 μF combination. The DC level across the 0.1 μF capacitor is fed back to A1's negative input. This feedback path forces the LM3524's output pulse width to vary in a highly linear fashion according to the potential at A1's positive input. The overall temperature-to-pulse width scale factor is adjusted with the "gain trim" potentiometer. The 1000 pF capacitor provides stable loop compensation. A1, an LM358, allows voltages very close to ground to be sensed. This provides greater input range than the LM3524's input amplifier, which has a common mode range of 1.8–3.4 V. The oscillator output pulse at pin 3 can be used to reset counters or other digital circuitry because it occurs just before the output pulse width begins.
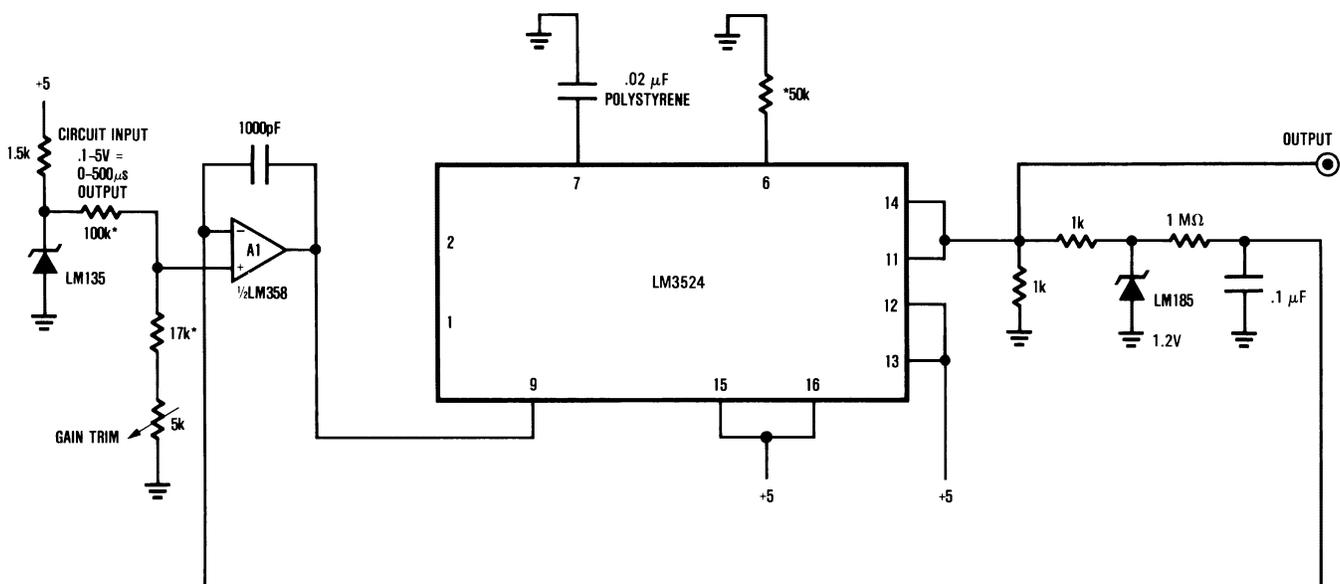

*Metal Film Resistor

Figure 5. Temperature-to-Pulse-Width Converter

3   RTD Temperature Controller

Figure 6 is another temperature circuit that uses the LM3524 to control the temperature of a small oven. Here, a platinum RTD is used as a sensor in a bridge circuit made up of the 2 kΩ resistors. When power is applied, the positive temperature coefficient platinum sensor is at a low value and the LM3524's positive input is at a higher potential than its negative input. This forces the output to go high, turning on the 2N3507 and driving the heater. When the servo point is reached, the duty cycle of the heater is reduced from 90% (full on) to whatever value is required to keep the oven at temperature. The 330k-4.7 μF combination at the internal input amplifier's output sets the servo gain at about 55 dB at 1 Hz, more than adequate for most thermal-control applications. The 0.02 μF-2.7k combination sets the pulse frequency at about 15 kHz, far above the 1 Hz pole of the servo gain. If the sensor is maintained in close thermal contact with the heater, this circuit will easily control to .1°C stability over widely varying ambients.
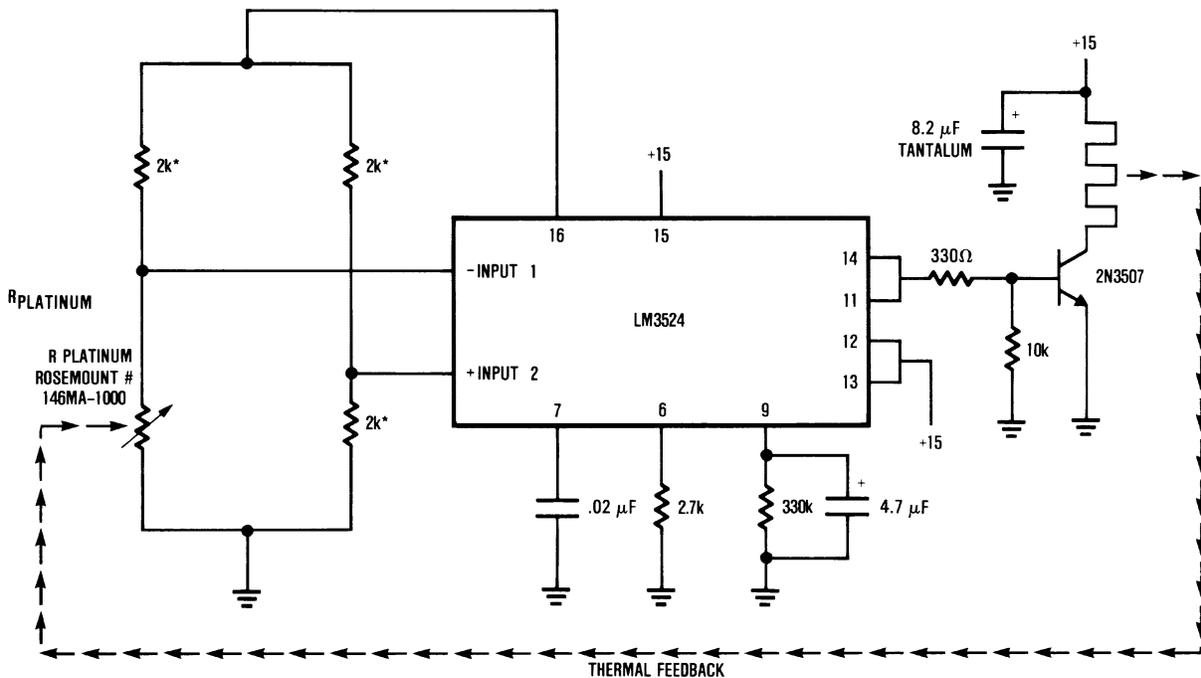
Figure 6. RTD Temperature Controller

4   "SENSORLESS" Motor Speed Control

Figure 7 shows the LM3524 in an arrangement that controls the speed of a motor without requiring the usual tachometer or other speed pick-off. This circuit uses the back EMF of the motor to bias a feedback loop, which controls motor speed. When power is applied, the positive input of the LM3524 is at a higher potential than the negative input. Under these conditions, the output of the LM3524 is biased full on (90% duty cycle). The output transistors, paralleled in the common emitter configuration, drive the 2N5023 and the motor turns. (LM3524 output is waveform A, Figure 8; waveform B is the 2N5023 collector.) The LM3524 output pulse is also used to drive a 1000 pF-500 kΩ differentiator network whose output is compared to the LM3524's internal 5 V reference. The result is a delayed pulse (Figure 8, waveform D), which is used to trigger an LF398 sample-hold IC. As the waveforms show, the sample-hold is gated high (ON) just as the 2N5023 collector stops supplying current to the motor. At this instant, the motor coils produce a flyback pulse, which is damped by the shunt diode. (Motor waveform is Figure 8, trace C). After the flyback pulse decays, the back EMF of the motor remains. This voltage is "remembered" by the sample-hold IC when the sample trigger pulse ceases and is used to complete the speed control loop back at the LM3524 input. The 10k-4k divider at the motor output insures the LF398's output will always be within the common range of the LM3524's input. The 10k-1 μF combination provides filtering during the time the LF398 is sampling. The diode associated with this time constant prevents any possible LF398 negative output from damaging the LM3524. The 10 MΩ resistor paralleling the 0.01 μF sampling capacitor prevents the servo from "hanging up" if this capacitor somehow manages to charge above the motor's back EMF value. The 39k-100 μF pair sets the loop frequency response. The maximum pulse-width-modulator duty cycle is clamped by the 2k-2k divider and diode at 80%, thus avoiding overshoot and aiding transient response at turn-on and during large positive step changes. The 60k-0.1 μF values at pins 6 and 7 set the pulse modulation frequency at 300 Hz.
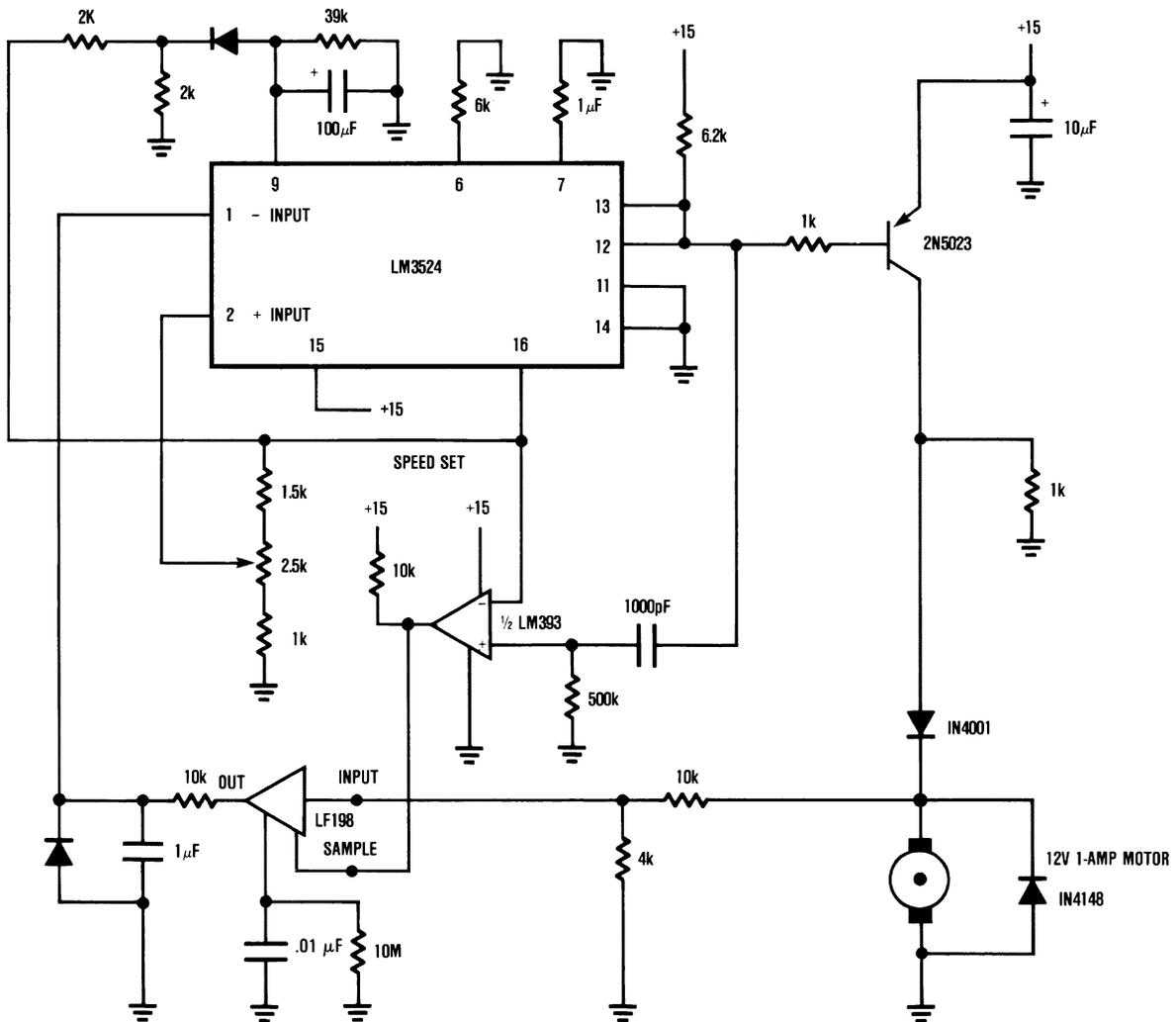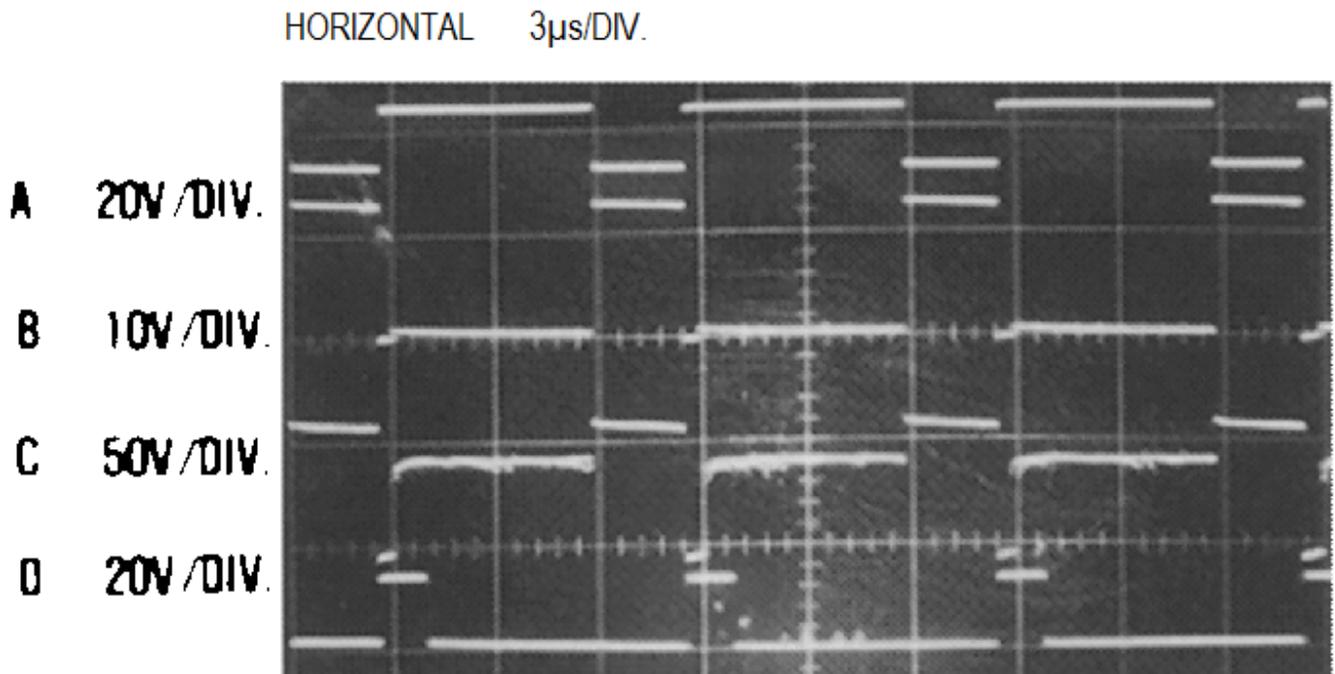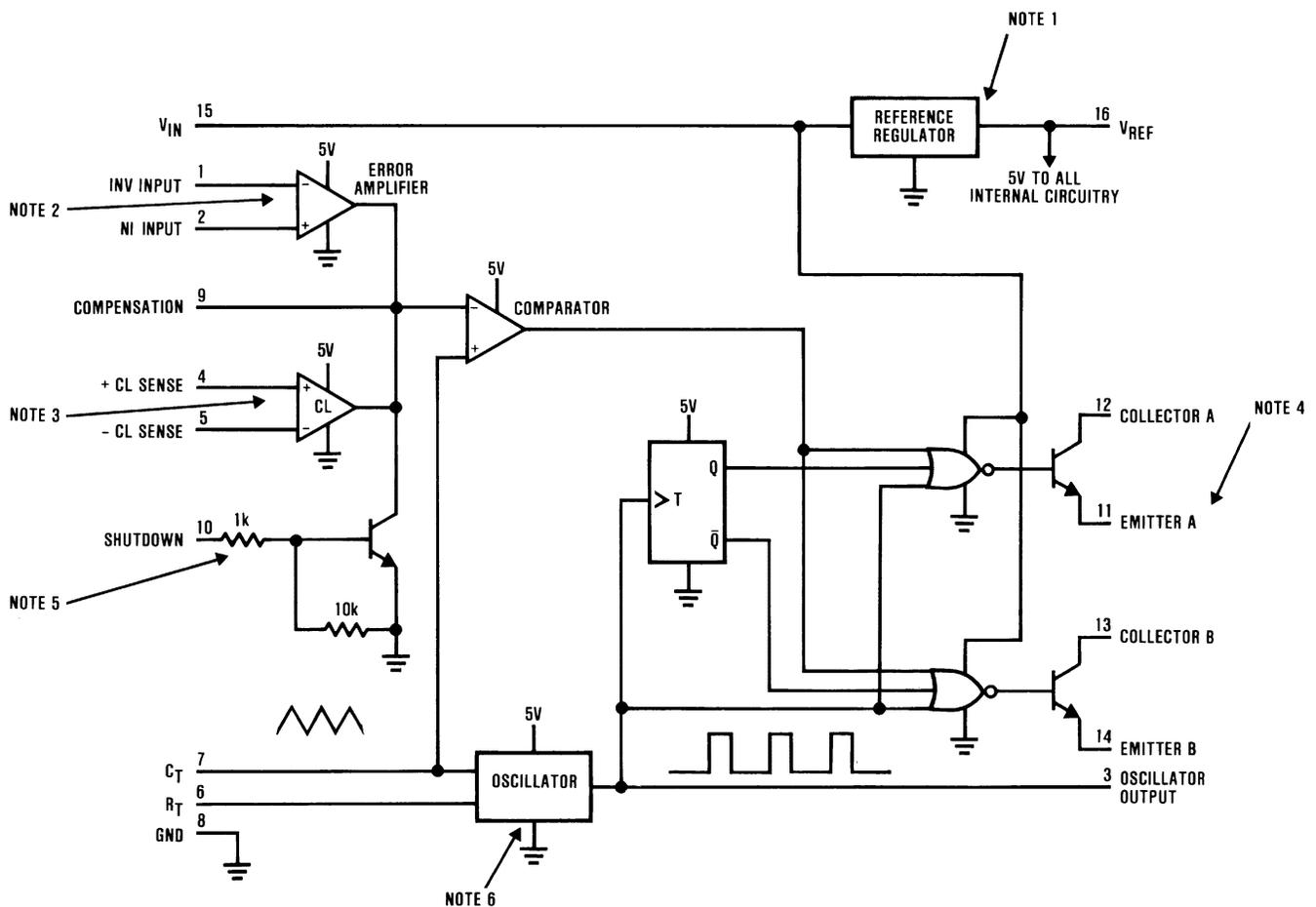
Figure 7. "SENSORLESS" Motor Speed Control

HORIZONTAL   3μs/DIV.

Figure 8. "SENSORLESS" Motor Speed Control Waveforms

5V 50 mA regulator available to user.

Transconductance diff. input amplifier. Gains from 40–80 dB available by resistor loading of output. 1.8–3.4V common mode input range.

Over current sense comparator −0.7 to 1V common mode input range.

Output transistors switch out of phase and may be paralleled. Up to 100 mA maximum output current.

Transistor may be used to strobe LM3524 into an off state at its outputs.

Oscillator typically frequency programmable for up to 100 kHz.

Figure 9. LM3524 at a Glance

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