Using the PT6100/6210/6300 as a Constant Current Source

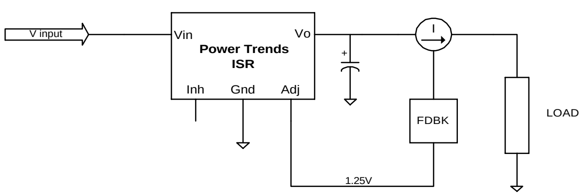
Overview

The Power Trends PT6100/6210/6300 Series Integrated Switching Regulator (ISR) is a self-contained device that was primarily designed and optimized to function as a voltage regulator, providing a constant output voltage to a variable load. With the addition of a minimal amount of external circuitry, however, the ISR can be transformed into a constant current source, providing a variable output voltage across a variable load in order to maintain a constant current. This allows the designer to utilize the outstanding characteristics of a switching regulator in an application which would normally employ a bulky, inefficient linear device.

Among the number of applications that can take advantage of this constant current source, include those required to drive light sources, motors, focus coils, and various types of sensors. Battery charging applications requiring high-current, bulk-charge states can also utilize this highly-efficient constant current source. Constant currents ranging from 100mA on up to 3A can be obtained depending on the ISR selected. The ISRs typically provide efficiencies on the order of 85% to 93%.

The constant current application utilizes the adjust pin of the ISR in conjunction with an external feedback mechanism (Figure 5). Depending on the application, the feedback mechanism could be as simple as a single current sense resistor. For other applications, the current sense resistor may need to be used along with a simple op amp stage.

Figure 5



The ISR is transformed into a constant current source by utilizing the ISR's adjust pin in conjunction with an external feedback mechanism.

Theory of Operation

Internally, the ISR's adjust pin is connected to the center-point of a high-impedance resistive divider network used to sample the output voltage of the ISR. For proper operation, the external feedback circuit used for the constant current source must appear as a low-impedance voltage source capable of dominant control of the adjust pin. For greatest accuracy, the characteristic impedance of this voltage source should be less than 1kΩ. The use of a typical op amp stage or a current-driven, low-impedance sense resistor are two methods of establishing this dominant voltage source.

Normally, the ISR's internal circuitry would monitor and regulate its output voltage so as to maintain a voltage of 1.25V at its adjust pin. The addition of the external feedback circuit will, instead, force the ISR to monitor and regulate its output current in order to maintain the same 1.25V at the adjust pin. The external circuit makes use of a current sense resistor which provides a voltage translation of the delivered load current. This current to voltage translation is scaled so that the desired output current equates to a voltage of 1.25V. The scaling is accomplished by selecting the value of the current sense resistor and the gain of any associated op amp stage. Efficiency and noise immunity are two things to consider when choosing the value of the current sense resistor and any associated gain. A compromise needs to be made between the voltage drop developed across the resistor and the power dissipated by the resistor. Where possible, a good rule of thumb is to select a resistor value that will develop a voltage drop on the order of 100 mV at the desired output current.

Application

The constant current source can be designed to accommodate either ground-referenced or floating load configurations. For a *ground-referenced load* (Figures 6A and 6B), the current sense resistor is placed directly in series with the output of the ISR and the load. The voltage drop across the resistor, hence the current, is measured differentially using an op amp employed as a difference amplifier. Any necessary gain is built into the diff amp stage . Adjustment of the output current can be accomplished through an additional op amp stage configured as a variable-gain, non-inverting amplifier.

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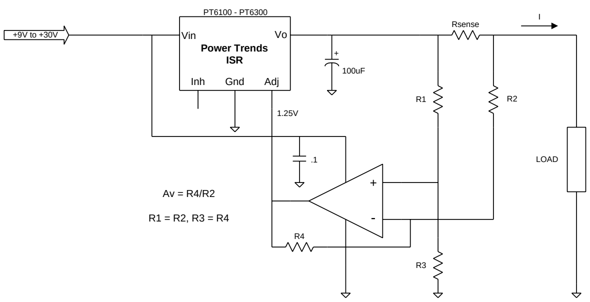
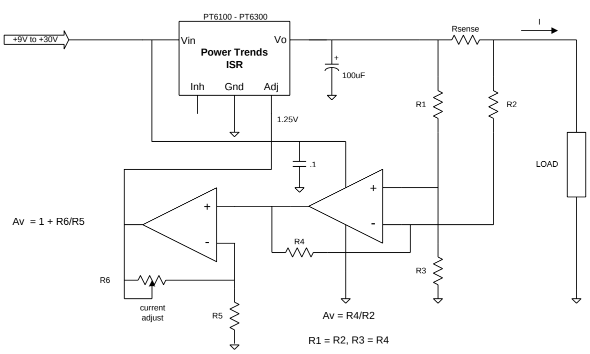
Figure 6A



The ground-referenced-load constant current source utilizes an op amp employed as a difference amplifier to monitor the voltage drop across a current sense resistor (Rsense).

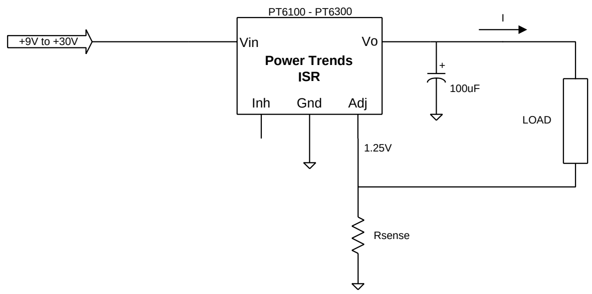
Figure 6B



The ground-referenced-load constant current source can be made adjustable by following the diff amp stage with a variable-gain, non-inverting op amp stage.

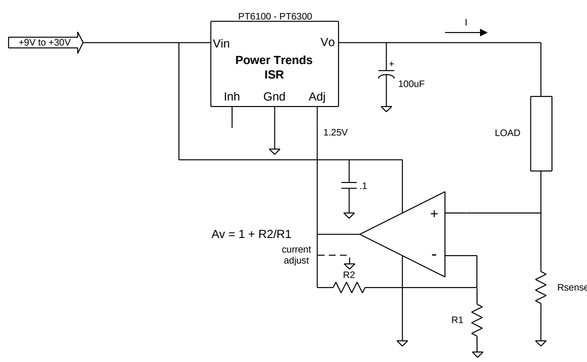
For a *floating load* configuration (Figures 7A and 7B), the current sense resistor is placed in series with the return end of the load and ground. In its simplest form, the voltage drop across the resistor, hence the current, is monitored via a direct connection to the ISR's adjust pin. Since the adjust pin looks like a relatively high impedance, it can be assumed that the entire load current flows through the low-impedance current sense resistor. In cases where efficiency outweighs simplicity, a non-inverting op amp stage with gain can be used along with a much smaller value of current sense resistor. The gain of the non-inverting amplifier can be made variable to allow for adjustment of the output current.

Figure 7A



The floating-load constant current source is the simplest of all configurations, requiring only a current sense resistor (Rsense) that connects directly to the ISR's adjust pin.

Figure 7B



A more efficient version of the floating-load constant current source employs a lower value current sense resistor and an op amp stage with gain.The current can be adjusted using variable gain.

Feedback Considerations

As with any feedback system, stability of the feedback loop needs to be considered. Typically, constant current sources are used to drive relatively slow responding loads where transient response is not of significant concern. For most cases, the external feedback loop can be compensated with a simple low-frequency pole. In general, stability should not be an issue if this pole is selected so that the unity gain (0dB) crossover frequency of the external circuit is limited to 5kHz.

In any case, it is recommended that the designer analyze the specific conditions of the application, and compensate the feedback loop to insure stable operation. This can best be accomplished by using a network analyzer and an injection amplifier. Bode plots can then be obtained to determine adequate gain and phase margins.

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ISR Selection

The Power Trends PT6100, PT6210, and PT6300 Series ISRs are 1, 2, and 3 amp devices, respectively. The appropriate ISR should be selected for the desired output current. Performance specifications can be based on the specs developed for standard voltage operation. Once the proper current rating has been determined, any of the ISRs within that particular family can be used for the constant current source, regardless of the factory-trimmed output voltage. The PT6103, PT6214, and PT6304 (12 volt) ISRs are preferred, however, in that their internal feedback dividers are higher impedance, providing for less error.

Conditions

Even though configured as a constant current source, the ISR still functions as a basic buck-type regulator and requires a certain amount of headroom between the input and output voltages to guarantee regulation. The required headroom for the PT6100/ 6210/6300 Series ISR is typically 4 volts. This means that at the desired load current, the voltage developed across the load and the drop associated with the current sense resistor should not exceed (Vin - 4V). It should also be noted that under open-circuit load conditions, the output voltage of the ISR will approach the input voltage due to the absence of sensed load current. Knowing these conditions, the constant current source should be designed so that the output voltage of the ISR cannot exceed 22 volts, so as not to exceed the ratings of the ISR's internal components.

Construction

Even though the load may be remotely located, the current sense resistor and the op amp stages should be located in close proximity to the ISR. A good ground plane, adequate bypassing, and high-frequency layout techniques should be employed. The proper op amp should be selected for the application. In particular, the differential input and common-mode input voltages need to be considered. The op amp should be designed for single supply operation and have a common-mode input range that includes ground. The popular LM324 (quad) and LM358 (dual) op amps are a good fit for any of the described configurations.

Accuracy of the constant current source will be dependent upon the precision of the external components. Ideally, the external resistors used should be of 1% accuracy or better. Among the choices for the current sense resistor, Dale's WSL-type surface mount resistors offer extremely low resistance at 1% tolerance and are available in ¼ watt, ½ watt, and 1 watt power ratings.

Examples

For a given application, the current through a filament-type lamp needs to be maintained at 1.2A. The input source is 24 volts and the nominal voltage of the lamp is approximately 12 volts. In one instance the lamp needs to be referenced to chassis ground, while in another it is used as a floating (two-leaded) device. Due to fluctuations in the resistance of the lamp, a constant voltage regulator will not guarantee a constant current. The use of a constant current source provides an ideal solution for this application.

For both instances, the Power Trends PT6214 (2A) ISR can be used to provide the 1.2A. With an input voltage of 24 volts and a nominal lamp voltage of 12 volts, there is plenty of headroom to guarantee regulation.

For the ground-referenced lamp (Figure 8), the circuit previously shown in Figure 6A can be utilized. For the desired output current of 1.2A, a 100mΩ current sense resistor will yield a voltage drop of 120mV. In order to equate this 120mV drop to 1.25V at the adjust pin, the gain of the op amp stage needs to be 10.4. Therefore, if R1 and R2 are selected as 1kΩ, R3 and R4 will need to be 10.4kΩ.

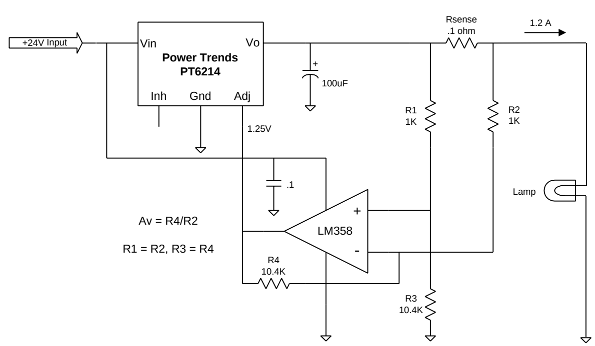
. . . . For Iout = 1.2A and R_{sense} = 0.1Ω,
. . . . V_{Rsense} = 1.2A x 0.1Ω = 120 mV

. . . . For Vadj = 1.25V,
. . . . Av = 1.25V / 120mV = 10.4

. . . . For R1 = R2 = 1kΩ
. . . . and R3 = R4,

. . . . Since Av = R4 / R2,
. . . . R4 = Av x R2 = 10.4 x 1kΩ = 10.4kΩ

Figure 8



This constant current source uses the PT6214 ISR to provide a constant 1.2A to a ground-referenced lamp.

For the floating lamp (Figure 9), the circuit previously shown in Figure 7A can be utilized. For the desired output current of 1.2A, a current sense resistor of 1.04Ω will need to be used to develop 1.25V at the adjust pin. It should be noted that even though this solution is very simple, the fact that the current sense resistor will dissipate 1.5 watts doesn't make it the most efficient approach. A more efficient solution would be to use the circuit of Figure 7B with a current

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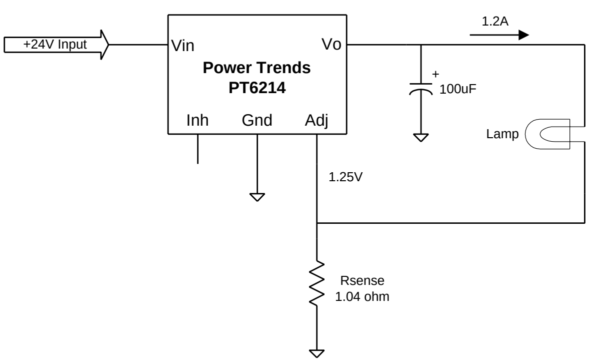
sense resistor of 100mΩ and an op amp gain of 10.4.

. . . . For Iout = 1.2A,
. . . . assume Iout = I_{Rsense}

. . . . For Vadj = 1.25V,
. . . . R_{sense} = 1.25V / 1.2A = 1.04Ω

Figure 9



This simple constant current source uses the PT6214 ISR to provide a constant 1.2A to a floating (two-leaded) lamp.

Constant Intensity Source

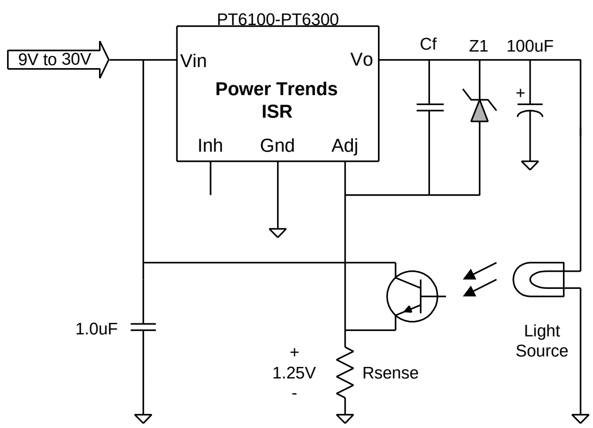
The versatility of the Power Trends PT6100/ 6210/6300 Series ISR becomes evident with its use as a constant light intensity source. Referring to the circuit in Figure 10, the external feedback mechanism is shown to consist of a light source, the light medium, a photo detector, and a current sense resistor. This external feedback circuit forces the ISR to regulate the output intensity of the light source in order to maintain a voltage of 1.25V at the ISR's adjust pin. A photo-transistor is employed as an emitter-follower and produces a certain photo-detection current at the desired light intensity. The detection current flows through the low-impedance current sense resistor which is sized to develop a voltage drop of 1.25V. In effect, the ISR regulates the photo-detection current sourced by the photo-transistor, which should correspond to the desired light intensity.

For greatest accuracy, the value of the current sense resistor should be less than 1kΩ. Depending on the response characteristics of the load and the detector used, external compensation (such as Cf) may need to be incorporated to insure stable operation of the feedback loop.

Similar to the constant current source, the appropriate ISR needs to be selected to accommodate the current demand of the light source. Also, to meet the required headroom between the input and output voltage of the ISR, the voltage developed across the light source should not exceed (Vin-4V).

Optional zener diode, Z1, may need to be used to limit the maximum output voltage of the ISR or the intensity of the light source. This may become necessary in cases where the desired light intensity cannot be obtained due to degradation of the light source or an obstructed light path. The value of Z1 is chosen in order to clamp the output voltage to (VZ1 + 1.25V). Without Z1, the output voltage of the ISR could approach the input voltage in an effort to obtain the desired light intensity. As in the case of the constant current source, the constant intensity source should be designed so that the output voltage of the ISR cannot exceed 22V.

Figure 10



An external feedback mechanism is used to transform the ISR into a constant light intensity source. The feedback mechanism consists of the light source, the light medium, a photo detector, and a current sense resistor.

Example

Assume that at the desired light intensity, the photo detection current = 5mA.

Then, Rsense = 1.25V / 5mA = 250Ω

The closed loop will regulate the 1.25V across the 250Ω resistor, maintaining a constant photo-transistor current of 5mA. The maintained 5mA detection current corresponds to a regulated intensity from the light source.

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