Precision method for laser diode emission control

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In many applications where light is used to control a process, it is important to maintain a constant light level. Some systems use a simple LED or laser diode to create a light source and provide illumination. However, these light sources will degrade with time even if initial calibration is applied. As an LED ages, its current-to-light emission ratio degrades.

To maintain the factory-set emission level over time, a control circuit is needed to monitor the emission and control the current being supplied to the light emitter. This configuration is ideal in photometric applications that require accurate light levels, control applications for accurate optical positioning of servo mechanisms and test equipment for optical references. **Figure 1** shows a block diagram of such a system.

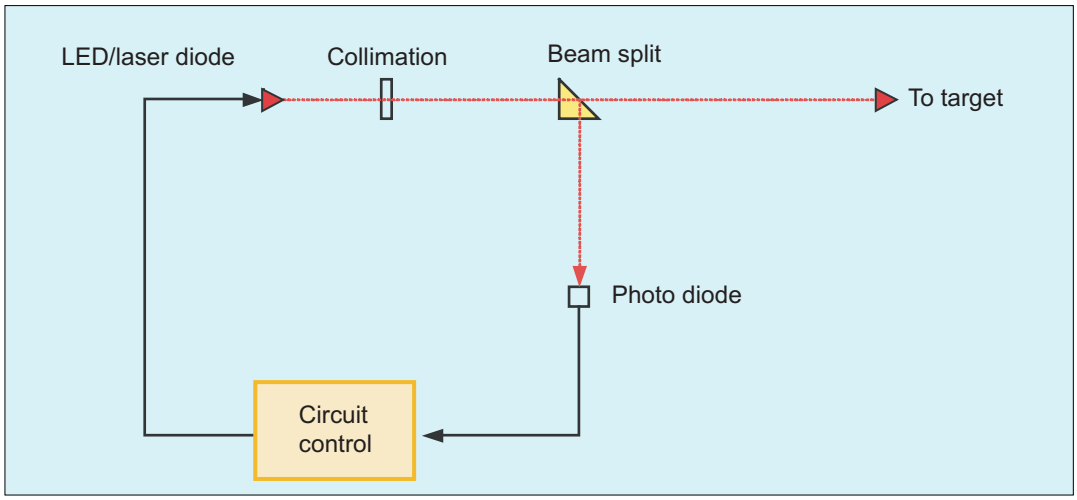

Figure 1: Control circuit monitors the emission and regulates the current supplied to the light emitter.

Photodiodes 101

A silicon photodiode is similar to PN junction diodes except that the P layer is very thin. The thickness of the P layer is adjusted for the wavelength of light to be detected. A photodiode also has capacitance, as does its non-photo cousin, which is directly proportional to the reverse bias voltage placed across it. The typical value ranges from 2-20pF.

Photodiodes have two terminals: cathode and anode. The diode can be used in either the forward mode (current flowing from the anode to the cathode) or in reverse mode (current flowing from the cathode to the anode). When using a photodiode in reverse mode (anode is negative), it is extremely linear with respect to illumination of a given frequency, which is a good thing. When things are linear, building a control circuit is much easier.

Prototype design

In **Figure 2**, a prototype circuit is used to analyze a control loop with an operation amplifier. The circuit drives a PNP transistor, which supplies current to an LED to generate light emission. A portion of this emission falls on the photodiode, which converts it to a very small current–typically 10μA or so. In this case, the diode is used in reverse mode so when no light is present, there is nothing but leakage current (also known as the "dark current") in the photodiode and the amplifier is in overload. This condition pulls current limited by a resistor from the base of the transistor, initially placing it in saturation. Once current starts to flow through the transistor, the LED or laser diode will begin to emit light. The photodiode will convert a portion of this light to a current, which flows through R_G. As the current increases, so will the voltage drop developing across R_G. As that voltage approaches V_{bias} (which is ground in **Figure 2**), the loop will close and maintain the correct drive to the transistor to maintain the current in the LED and keep a constant light level (or current in the photodiode). This forms the basis for the DC-analysis of the circuit. **Figure 3** shows an implementation of the circuit using an LMV2011 precision operation amplifier. The reference voltage is generated using an LM4041-1.2 shunt reference, which provides a fixed 1.225V reference voltage. The current in the reference is set at approximately 10mA, which is the middle of its operating range.

V_{bias} is generated by two 1% precision resistors set at approximately 1V. To calculate the photodiode current at which the control loop is closed, the difference between V_{ref} and V_{bias} is divided by R_G. Note that V_{bias} must be less then V_{ref} for this circuit to work. For a photodiode current of 10mA, R_G is 0.2 x 10E-6 or 20.0kΩ. The PN200A PNP transistor's base current is limited by a 4.7kΩ resistor, which sets the limit at about 1mA. The transistor has a β of approximately 100, so the maximum current the transistor can supply is about 100mA, which would exceed the thermal dissipation of

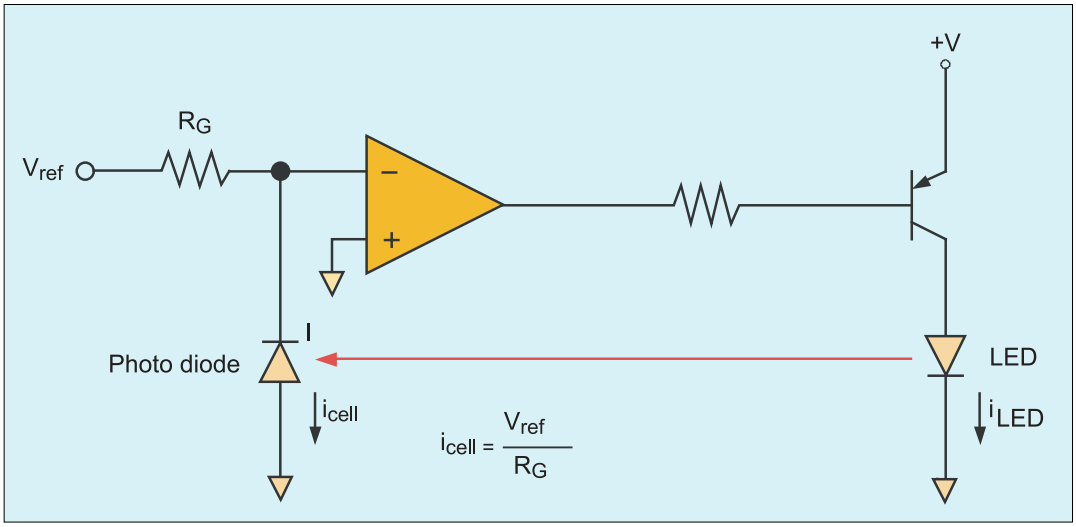

Figure 2: Prototype control circuit is used for analysis of a control loop using an operation amplifier. The circuit drives a PNP transistor, which supplies current to an LED to generate light emission.

the tiny SOT-23 package. To prevent thermal runaway in the transistor, the collector current is limited by a resistor in series with the LED or laser diode to the operating maximum of the diode. If more current is required, a transistor with a larger collector current should be used along with a larger package such as SOT-223. To limit the bandwidth of the circuit to maintain stability, the amplifier is rolled off at about 250kHz by a 15pF capacitor in parallel with the photodiode capacitance (also around 15pF with the $1.2V_{bias}$).

With a simple operational amplifier circuit, it is quite easy to create an accurate light level for many different applications. As the light emitter ages, the control loop steadies at a constant level by adjusting the current flowing in the LED. □

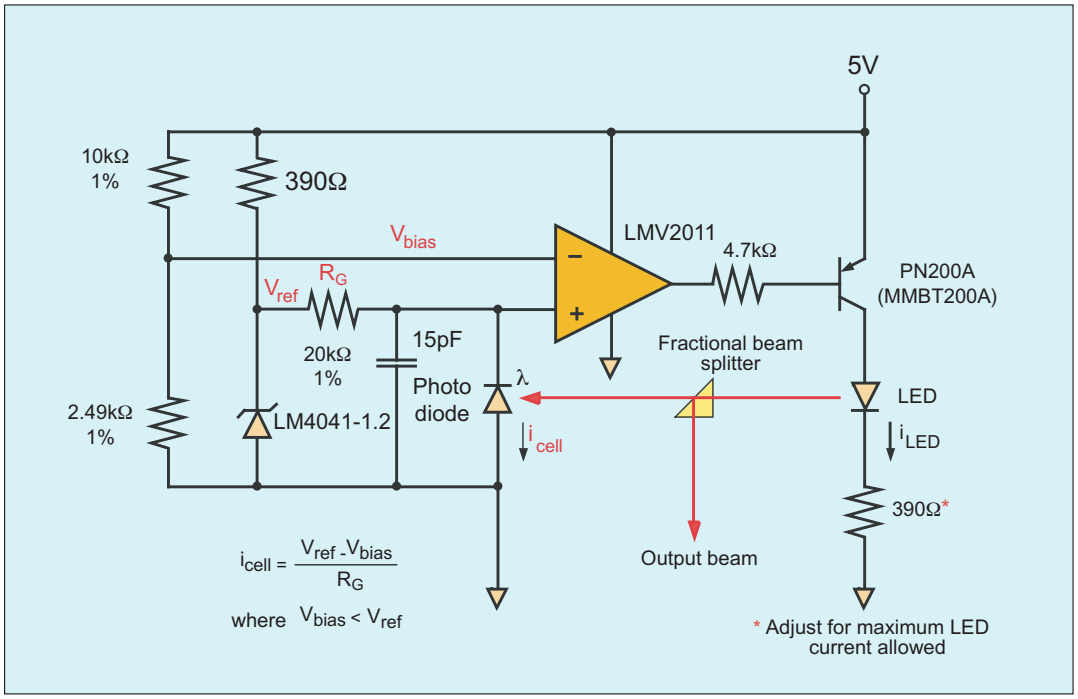

Figure 3: The reference voltage is generated using LM4041-1.2 shunt reference, which provides a fixed 1.225V reference voltage. The current in the reference is set at approximately 10mA.