Application Note

Laser Biasing and Optical Communication Applications with the AFE11612-SEP

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ABSTRACT

This application note details how the AFE11612-SEP can be used in a multitude of optical communication applications, such as laser biasing, EML negative bias, and photodiode detection and measurement.

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1 Introduction

Optical and optical networking (ONET) applications require a variety of subsystems. These systems include:

- Communications Payload
- Optical Imaging Payload
- Optical Module

For optical and ONET applications in space, device selection can be limited and expensive. The AFE11612-SEP is a versatile, space-rated, integrated device that can consolidate the circuitry needed for optical and ONET subsystems. The AFE11612-SEP features twelve 12-bit digital-to-analog converters (DAC), a sixteen channel 12-bit analog-to-digital converter (ADC), and two remote temperature sensors.

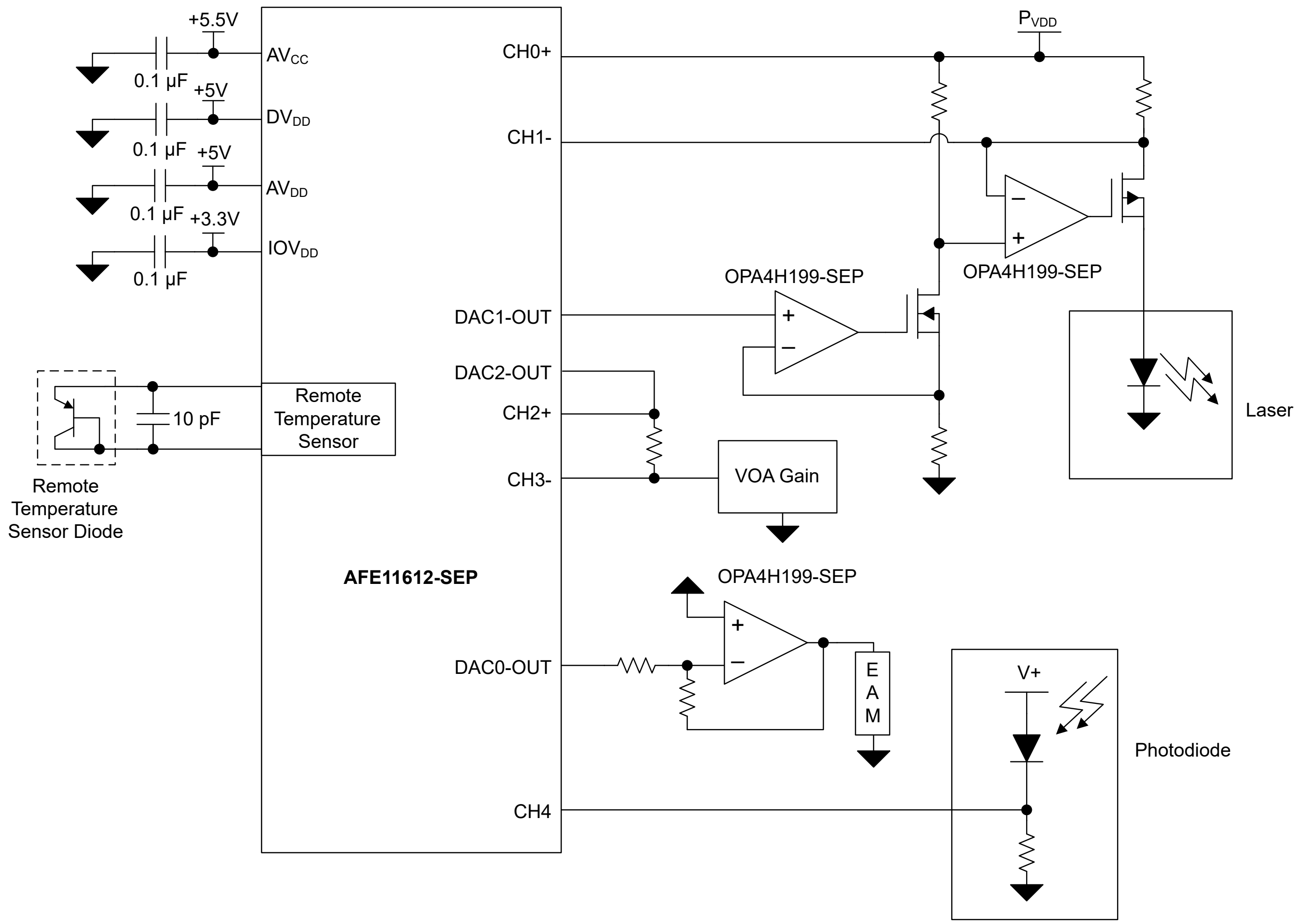

Figure 1-1. AFE11612-SEP Optical Networking Application

2 Laser and Semiconductor Optical Amplifier Biasing

Laser diodes and semiconductor optical amplifiers (SOAs) require a precision current source and current monitoring to be accurately biased. The AFE11612-SEP has twelve 12-bit DACs that can be configured to be a precision current source with external circuitry. The circuit in Figure 2-1 uses the AFE11612-SEP DAC outputs, external operational amplifiers (op amps), and external MOSFETs to supply a programmable current to a ground-referenced load.

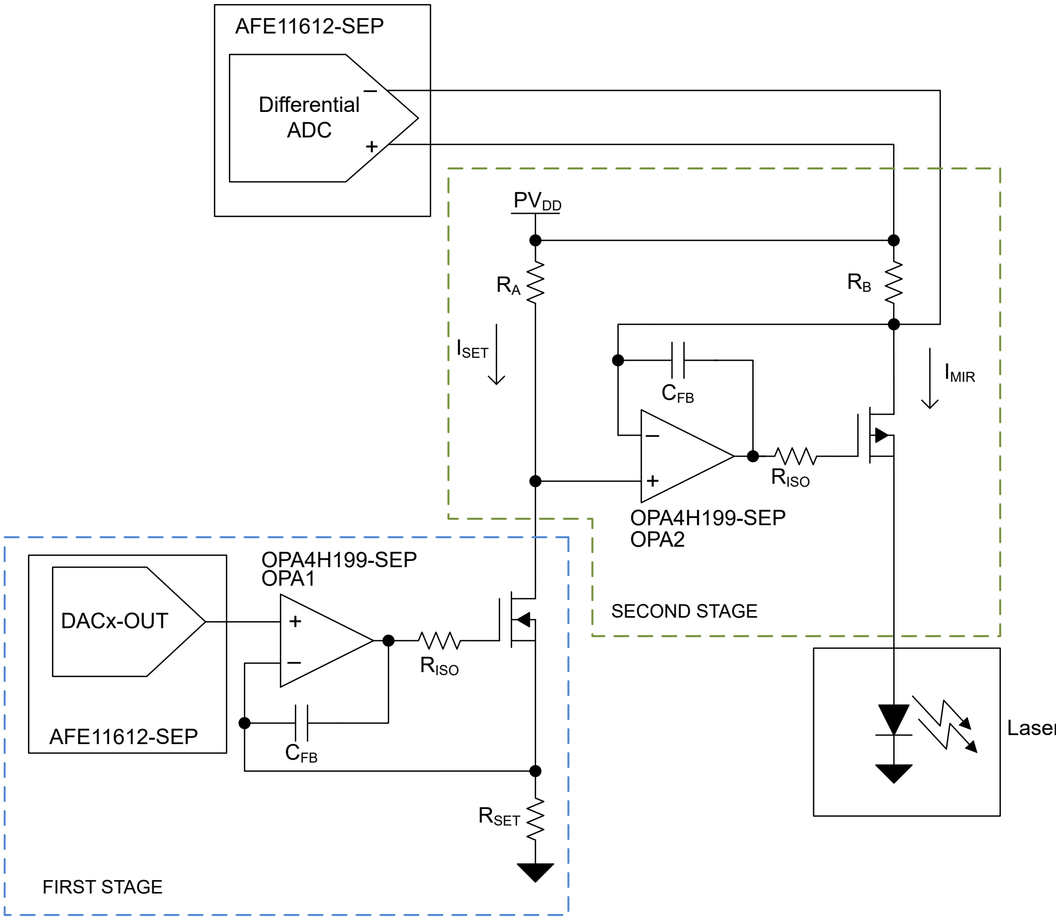

Figure 2-1. Laser Diode Bias Circuit

The first op amp stage uses R_{SET} and the DAC output voltage (V_{DAC}) to set the reference current. V_{DAC} is applied to the noninverting input of OPA1, which sets the high-side of R_{SET} to the same voltage. This reference current (I_{SET}) is calculated with Equation 1.

$$I_{SET} = \frac{V_{DAC}}{R_{SET}} \quad (1)$$

The second op amp stage is a current-mirror with a gain set by R_A and R_B. The current flowing through R_A is equal to I_{SET}. This creates a voltage drop across R_A. R_B has the same voltage drop due to the op amp OPA2 feedback forcing the voltage at the low-side of R_B. Thus, with R_A and R_B having the same voltage drop, the current flowing through R_B can be tuned by picking specific resistor values. This current (I_{MIR}) is the current that is used by the load. Use Equation 2 and Equation 3 to calculate the current gain.

$$I_{SET} \times R_A = I_{MIR} \times R_B \quad (2)$$

$$\text{Current Gain} = \frac{I_{SET}}{I_{MIR}} = \frac{R_A}{R_B} \quad (3)$$

The total gain of the system can be calculated by Equation 4.

$$I_{MIR} = \frac{V_{DAC} \times R_A}{R_{SET} \times R_B} \quad (4)$$

For additional information on using voltage DACs to create programmable current sources, see *8-Channel, 16-Bit, 200-mA Current Output, Digital-to-Analog Converter Reference Design* and *Programmable, Two-Stage, High-Side Current Source Current*.

Additionally, the AFE11612-SEP features an ADC with differential inputs which can assist in measuring the voltage differential across R_B to monitor current. The AFE11612-SEP ADC has a range of 5 V, so the P_{VDD} voltage must be taken into account when using the ADC for measurements. For use in higher voltage applications, an INA or a voltage divider circuit can be used to measure the voltage across R_B, as seen in Figure 2-2.

The AFE11612-SEP also has two remote temperature monitors that trigger an alarm when they detect temperature that exceeds a user-determined value. These can be placed near temperature sensitive components to make sure that the host is informed when the devices are overheating.

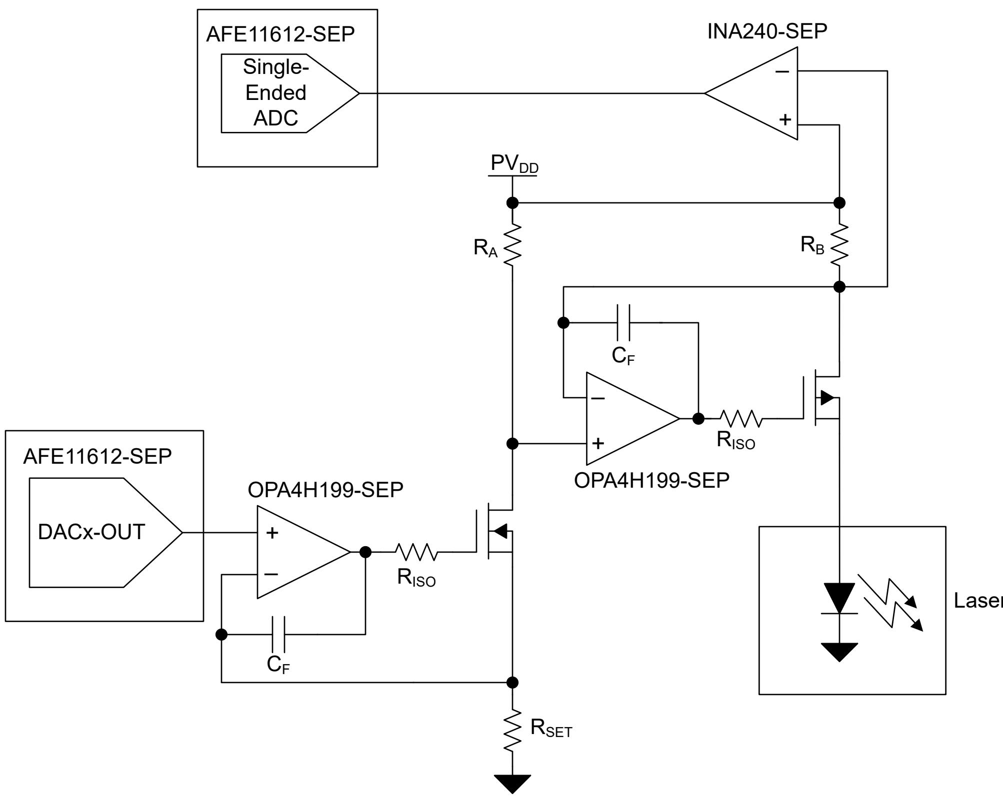

Figure 2-2. Laser Diode Bias Circuit with INA

3 EML Negative Bias Voltage

Optical networking applications that use an electro-absorption modulated laser (EML) require a negative voltage to bias the integrated electro-absorption modulator (EAM). The AFE11612-SEP has an internal 2.5-V reference that scales the DAC output range from 0 V to 5 V. The DAC output can be converted to a negative voltage through the use of an inverting op amp circuit that is powered by a negative power supply. The circuit in Figure 3-1 uses the op amp OPA4H199-SEP to offset and scale the 5-V output range to 0 V to -5 V. The feedback resistor ratio can be selected for an increased or decreased output range. The plot in Figure 3-2 shows the OPA output voltage vs the input DAC voltage.

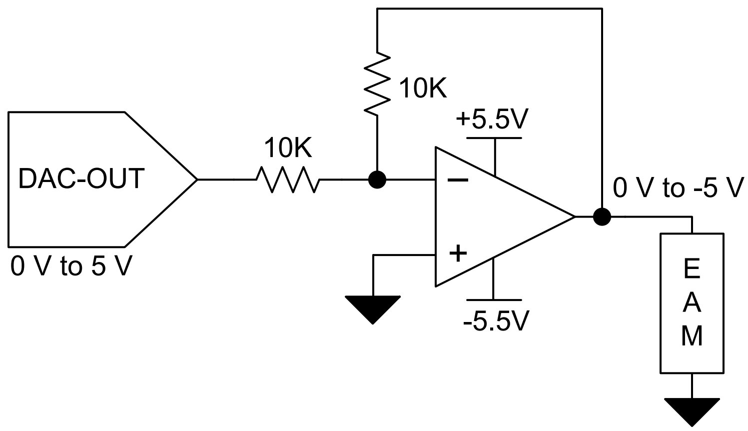

Figure 3-1. Inverting Op Amp Circuit

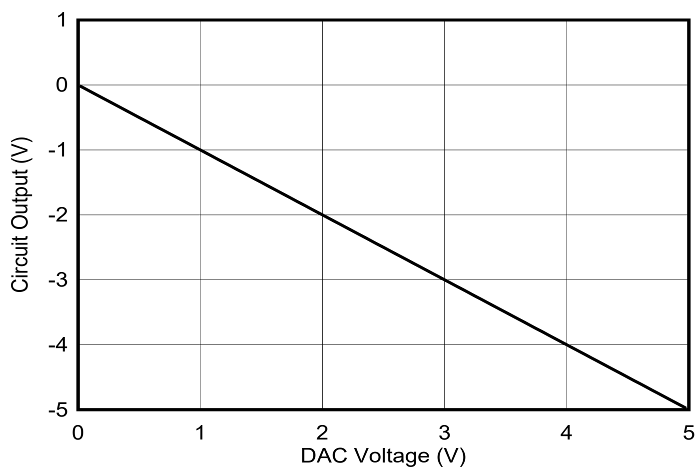

Figure 3-2. Inverting Op Amp Output

4 Photodiode Detection Measurement

The AFE11612-SEP has 16 ADC inputs that can be used for monitoring many functions, including measuring photodiode current. The device ADC is a successive-approximation register (SAR) ADC. SAR ADCs have an internal sampling capacitor which must be charged every time there is an ADC conversion. This capacitor must be charged within the sample acquisition time to ensure the ADC measures the voltage correctly. This is done using a charge-bucket filter with an external capacitor (C_{FILT}). The filter resistor (R_{FILT}) can be a low value so C_{FILT} can receive enough current to be charged for each sample. A sense resistor (R_{SENSE}) turns the photodiode current into a voltage, and the resistor should be selected such that the resulting voltage is within the ADC 5-V input range. Figure 4-1 shows the charge bucket circuit.

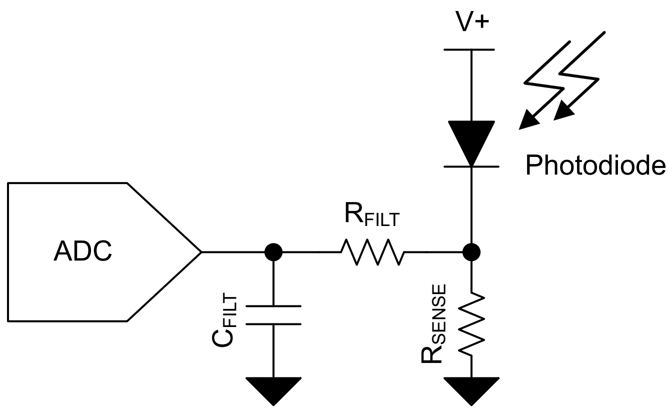

Figure 4-1. Photodiode Monitor Circuit

5 Variable Optical Attenuator Control

Variable optical attenuators (VOA) are commonly used in ONET applications to help control the light and power output of laser applications. The AFE11612-SEP DACs and differential ADCs can be used to control VOAs and also monitor the current and power of the attenuators. Similar to the laser current monitoring, an INA can be used instead of the AFE11612-SEP differential ADC inputs for higher voltage applications. Figure 5-1 shows a circuit that measures the current going into the VOA.

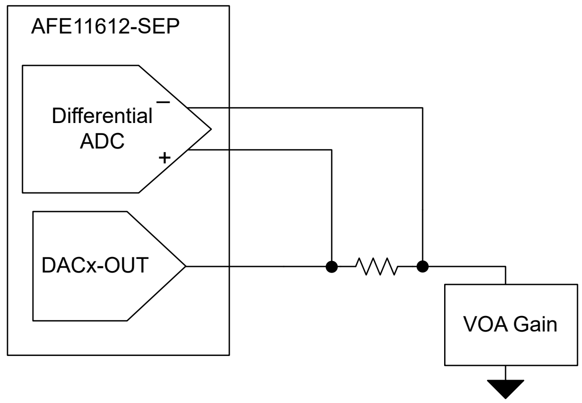

Figure 5-1. VOA Control Circuit

6 Summary

Space projects that require DACs and ADCs can be very costly and board insufficient, with limited amount of device options available. The multiple DACs and ADC inputs of the AFE11612-SEP make it an incredibly flexible tool that can support and consolidate the building blocks for optical and ONET applications.

7 References

1. Texas Instruments, *AFE11612-SEP Radiation-Tolerant, Analog Monitor and Controller with Multichannel ADC, DACs, and Temperature Sensors*, data sheet.
2. Texas Instruments, *OPA4H199-SEP 40-V, Radiation Hardened, Rail-to-Rail Input/Output, Low Offset Voltage, Low Noise Op Amp in Space Enhanced Plastic*, data sheet.
3. Texas Instruments, *8-Channel, 16-Bit, 200-mA Current Output, Digital-to-Analog Converter Reference Design*.
4. Texas Instruments, *Programmable, Two-Stage, High-Side Current Source Current*, analog engineer's circuit.

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