

# SGM833A

## 140dB Range (1nA to 10mA)

### Logarithmic Current-to-Voltage Converter

## GENERAL DESCRIPTION

The SGM833A is a single-supply logarithmic current-to-voltage converter for measuring the low frequency current signals over a large range from 1nA to 10mA. With capabilities such as photodiode adaptive biasing, active-shielding (guard driving), output buffer amplifier conditioning and voltage reference on a single chip, this device is optimized for measuring the power of optical signals by using a photodiode operating in the photo current mode. The measured current is converted and compressed to a logarithmic voltage by using transistor I-V characteristics and a compensation circuit.

The SGM833A operates with a single 3V to 5.5V supply and is equipped with a disable input to shut down the device. The input current ( $I_{PD}$ ) is converted to an internal 40 $\mu$ A/dec logarithmic scaled current that is injected into an internal 5k $\Omega$  resistance to provide an output voltage with 10mV/dB (or 200mV/dec) logarithmic slope on the VLOG output pin. This slope can be reduced by an external shunt resistor. The intercept point (the output voltage corresponding to the selected intercept current) and the scale (to change the slope) can be adjusted by the on-chip buffer amplifier.

This device is available in a Green TQFN-3 $\times$ 3-16L package and is specified over a temperature range of -40 $^{\circ}$ C to +85 $^{\circ}$ C.

## FEATURES

- Patents Pending Proprietary Circuits
- Seven Full Decades Range
- 3V to 5.5V Single-Supply Operation
- Low Power and Temperature Stable
- Precise Trimmed Scaling
- 10mV/dB Logarithmic Slope at VLOG Pin
- 100pA Basic Logarithmic Intercept
- Simple Slope and Intercept Adjustments
- 15V/ $\mu$ s Slew Rate
- 3.3mA (TYP) Quiescent Current (Enabled)
- 9 $\mu$ A (TYP) Shutdown Current (Disabled)
- Available in a Green TQFN-3 $\times$ 3-16L Package

## APPLICATIONS

High Accuracy Optical Power Measurement  
Wide Range Baseband Log Data Compression  
Versatile Detector for Automatic Power Control Loops

## TYPICAL APPLICATION

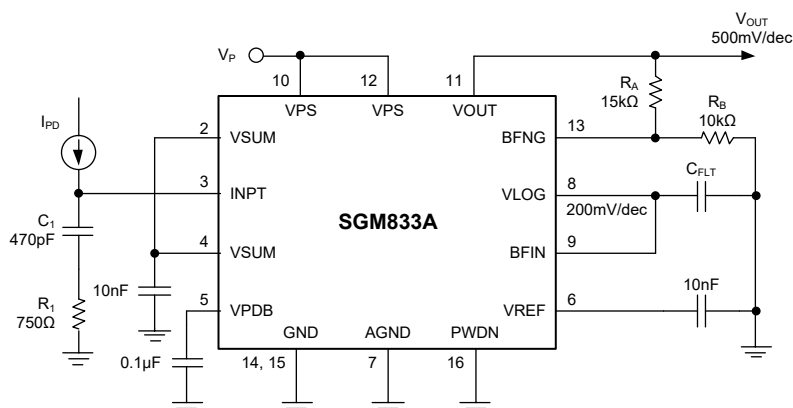


Figure 1. Typical Application Circuit

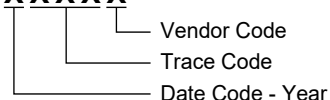
## PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM833A	TQFN-3×3-16L	-40°C to +85°C	SGM833AYTQ16G/TR	833ATQ XXXXX	Tape and Reel, 4000

## MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code.

XXXXX



Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage.....	6V
Input Current.....	20mA
Internal Power Dissipation .....	270mW
Package Thermal Resistance	
TQFN-3×3-16L, $\theta_{JA}$ .....	71°C/W
Junction Temperature .....	+150°C
Storage Temperature Range .....	-65°C to +150°C
Lead Temperature (Soldering, 10s) .....	+260°C
ESD Susceptibility	
HBM.....	4000V
CDM .....	1000V

## RECOMMENDED OPERATING CONDITIONS

Input Voltage Range .....	3V to 5.5V
Operating Ambient Temperature Range .....	-40°C to +85°C
Operating Junction Temperature Range .....	-40°C to +125°C

## OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

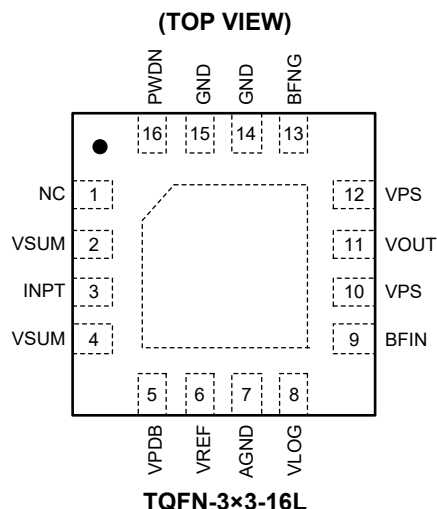
## ESD SENSITIVITY CAUTION

This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

## DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

## PIN CONFIGURATION



## PIN DESCRIPTION

PIN	NAME	FUNCTION
1	NC	No Connection. Pin labeled NC can be allowed to float, but it is better to connect this pin to ground. Avoid routing high-speed signals through this pin because noise coupling may result.
2, 4	VSUM	Guard Pins. These pins are located on both sides of the INPT pin and can be connected to the shield guard of the INPT current signal for active shielding.
3	INPT	Photodiode Current Input. INPT pin is typically connected to the photodiode anode. The photo current flows into the INPT pin. (The photodiode junction is slightly reverse biased to operate as detector.)
5	VPDB	Photodiode Bias Output. VPDB pin can be connected to the photodiode cathode to provide adaptive bias control. The adaptive bias increases the reverse bias voltage as diode current increases to compensate the resistive drops inside the diode and keeps a sufficient reverse bias across the junction, such that the diode current is only determined by the incoming optical power. Otherwise, leave the pin floating.
6	VREF	Output of the 2V Internal Voltage Reference. It can be used to set the intercept point for buffer output.
7	AGND	Analog Ground (Return for the output signals and VREF).
8	VLOG	Output of The Logarithmic Front-End. Output of the logarithmic converter with an internal shunt resistance is $R_{OUT} = 5k\Omega$ to ground. Provide a logarithmic output voltage with a 100pA intercept and a fixed 200mV/dec slope (200mV change for each 1-decade change in the input current). The lower margin of VLOG is less than 0.1V but cannot reach 0V. Therefore, for input currents below 1nA, this output is saturated (the intercept point is out of range). The VLOG output impedance is 5k $\Omega$ .
9	BFIN	Internal Buffer Amplifier Non-Inverting Input (High Impedance).
10, 12	VPS	Positive Supply, $V_P$ (3.0V to 5.5V).
11	VOUT	Internal Buffer Amplifier Output (Low Impedance).
13	BFNG	Internal Buffer Amplifier Inverting Input.
14, 15	GND	Power Supply Ground.
16	PWDN	Power-Down (Disable) Logic Input. Pulling this pin high will disable the device, and pulling this pin low will enable the device.
—	Exposed Pad	Connect the exposed pad to the VSUM pins to provide low leakage guard.

### ELECTRICAL CHARACTERISTICS

( $V_P = 5V$ ,  $T_J = -40^\circ C$  to  $+85^\circ C$ , typical values are at  $T_J = +25^\circ C$ , unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Interface (INPT, VSUM)						
Specified Current Range	Flows into INPT pin		1nA		10mA	
Input Node Voltage	Internally preset; can be altered	T <sub>J</sub> = +25°C	0.47	0.5	0.53	V
		T <sub>J</sub> = -40°C to +85°C	0.465	0.5	0.535	
Temperature Drift	T <sub>J</sub> = -40°C to +85°C			0.02		mV/°C
Input Guard Offset Voltage	V <sub>IN</sub> - V <sub>SUM</sub> , T <sub>J</sub> = +25°C		-20		20	mV
Photodiode Bias <sup>(1)</sup> (Established between VPDB and INPT)						
Minimum Value	I <sub>PD</sub> = 1nA, T <sub>J</sub> = +25°C		70	100		mV
Trans-Resistance				300		mV/mA
Logarithmic Output (VLOG)						
Slope	1μA < I <sub>PD</sub> < 1mA	T <sub>J</sub> = +25°C	194	200	207	mV/dec
		T <sub>J</sub> = 0°C to +70°C	192	200	209	
	1nA < I <sub>PD</sub> < 1μA	T <sub>J</sub> = +25°C	192	200	212	
		T <sub>J</sub> = 0°C to +70°C	189	200	214	
Intercept (I <sub>Z</sub> )	T <sub>J</sub> = +25°C		70	100	130	pA
	T <sub>J</sub> = 0°C to +70°C		60		140	
Law Conformance Error <sup>(2)</sup>	10nA < I <sub>PD</sub> < 1mA, peak error, T <sub>J</sub> = +25°C			0.05	1.1 <sup>(3)</sup>	dB
	1nA < I <sub>PD</sub> < 1mA, peak error, T <sub>J</sub> = +25°C			0.08	2 <sup>(3)</sup>	
Maximum Output Voltage				1.6		V
Minimum Output Voltage				0.1		V
Shunt Output Resistance (R <sub>OUT</sub> )	T <sub>J</sub> = +25°C		4.95	5	5.05	kΩ
Reference Output (VREF)						
Voltage (Referred to AGND)	T <sub>J</sub> = +25°C		1.98	2	2.02	V
	T <sub>J</sub> = -40°C to +85°C		1.97	2	2.03	
Output Resistance				0.1		Ω
Output Buffer Amplifier (BFIN, BFNG, VOUT)						
Input Offset Voltage	T <sub>J</sub> = +25°C		-20		20	mV
Input Bias Current	Flowing out of BFIN or BFNG pins			20		pA
Incremental Input Resistance (dv/di)				25		GΩ
Output High Voltage	Loaded with R <sub>L</sub> = 1kΩ to ground			V <sub>P</sub> - 0.1		V
Output Resistance				0.1		Ω
Wide-Band Noise <sup>(4)</sup>	I <sub>PD</sub> > 1μA			1		μV/√Hz
Small Signal Bandwidth <sup>(4)</sup>	I <sub>PD</sub> > 1μA			10		MHz
Slew Rate	0.2V to 4.8V output swing			15		V/μs

**ELECTRICAL CHARACTERISTICS (continued)**(V<sub>P</sub> = 5V, T<sub>J</sub> = -40°C to +85°C, typical values are at T<sub>J</sub> = +25°C, unless otherwise noted.)

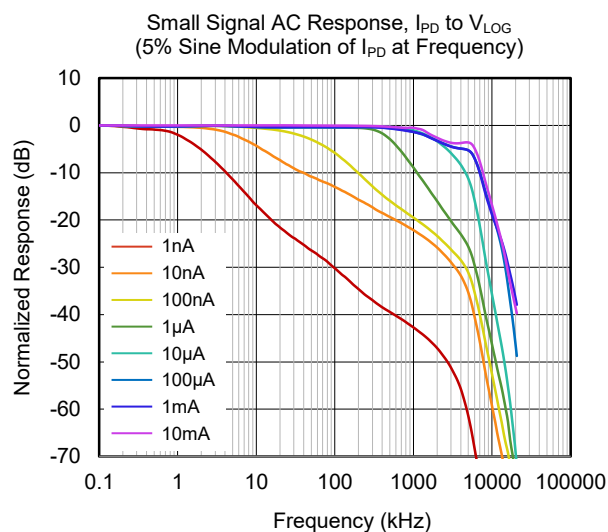
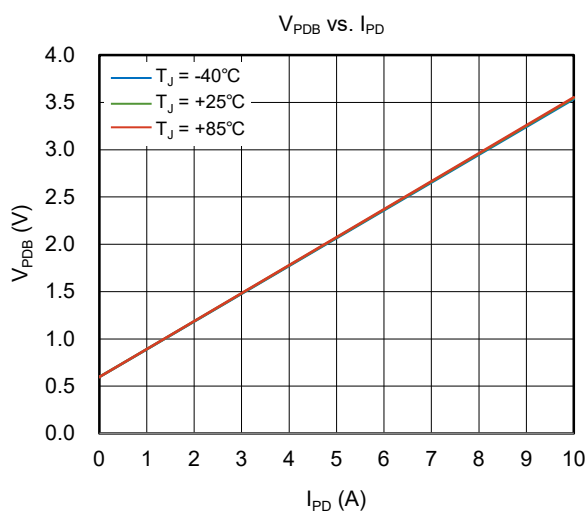
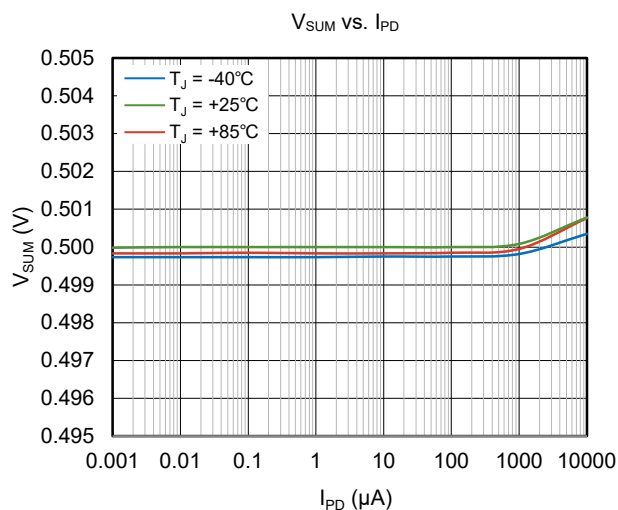
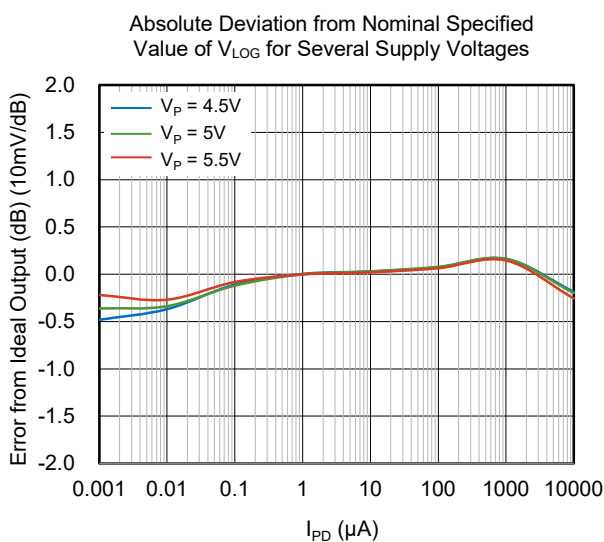
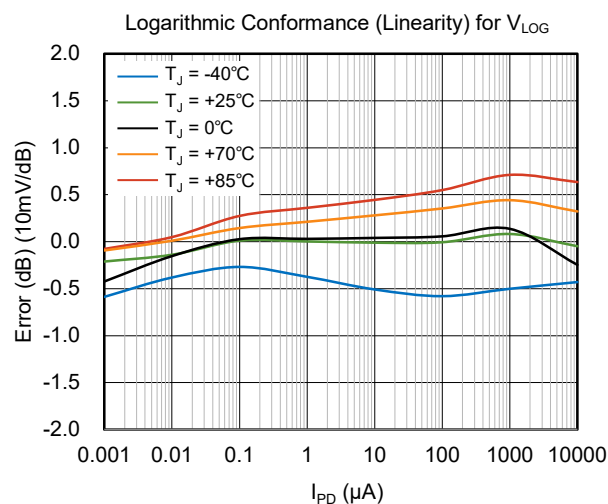
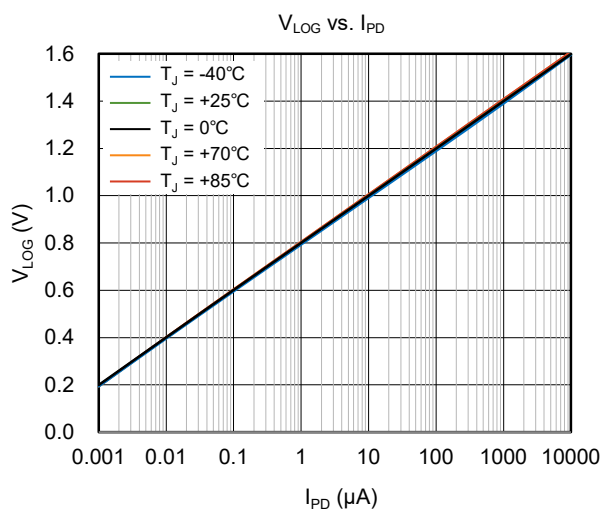
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Power-Down Input (PWDN)</b>					
Logic High Level Voltage	2.7V < V <sub>P</sub> < 5.5V	2			V
Logic Low Level Voltage	2.7V < V <sub>P</sub> < 5.5V			1	V
<b>Power Supply (VPS)</b>					
Positive Supply Voltage		3	5	5.5	V
Quiescent Current (Enabled)	T <sub>J</sub> = +25°C		3.3	5	mA
Shutdown Current (Disabled)			9		μA

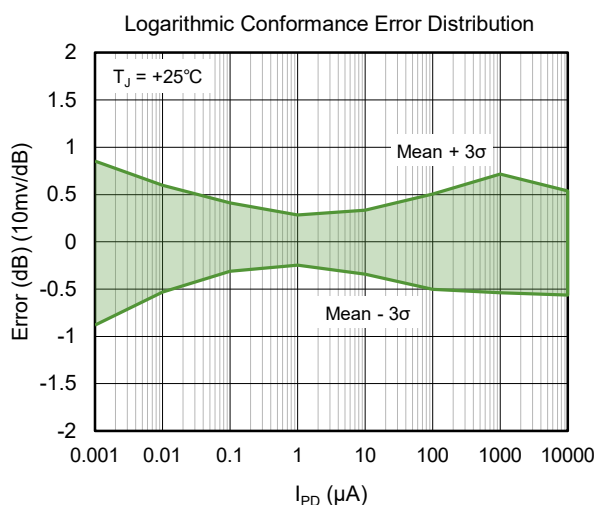
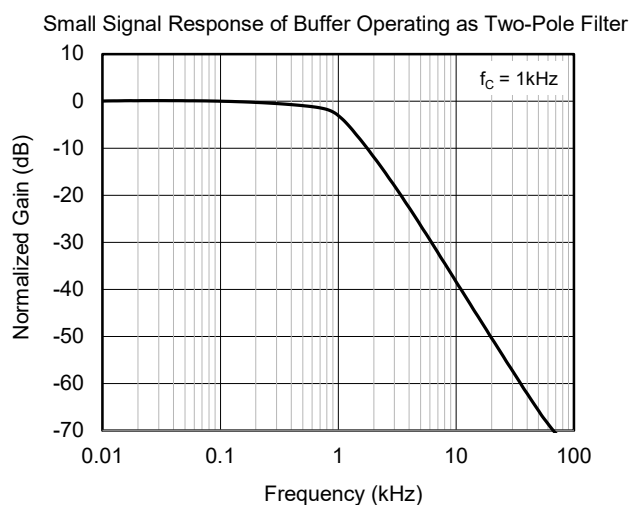
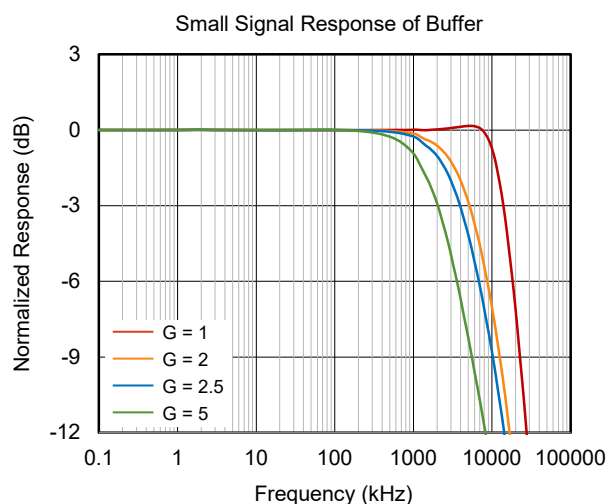
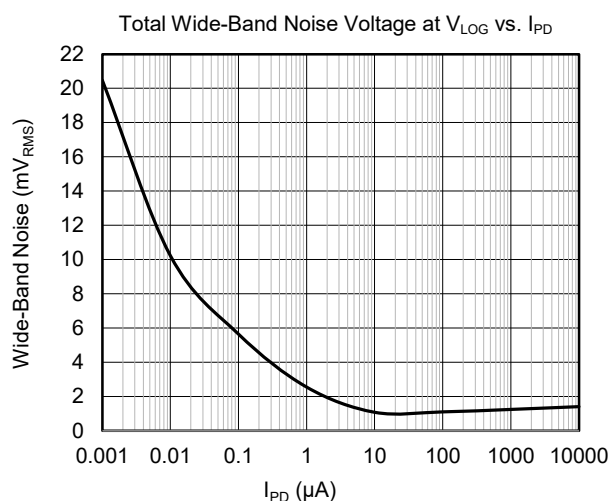
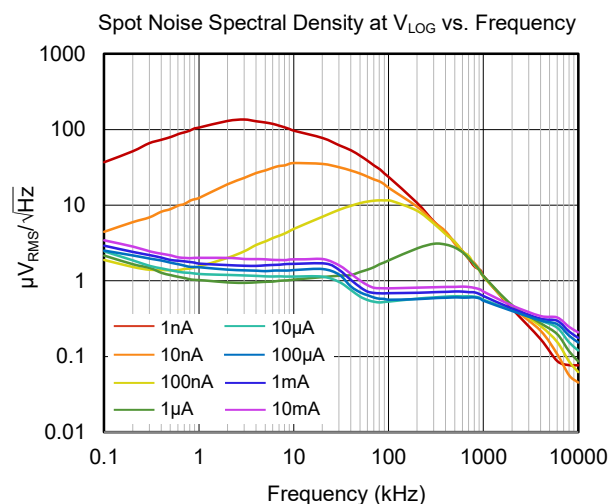
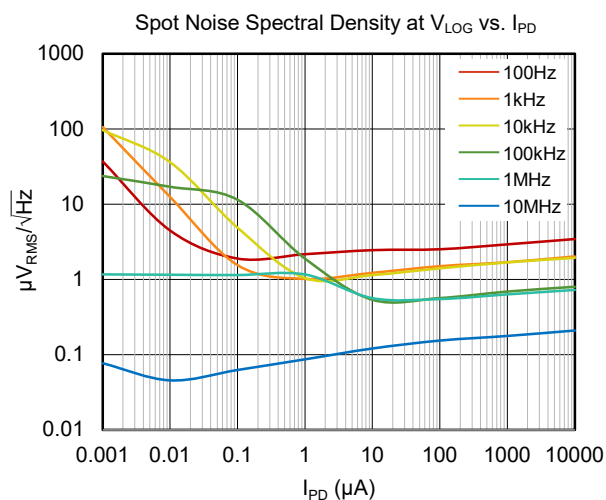
## NOTES:

1. This bias is internally arranged to track the input voltage at INPT; it is not specified relative to ground.
2. The deviation of VLOG from the ideal relationship expressed as  $V_{LOG} = \text{Slope} \times (I_{PD} - I_Z)$  with quantities expressed in logarithmic (dB) scale.
3. The specified minimum and maximum values are guaranteed by ATE, excluding the reliability shift.
4. Output noise and incremental bandwidth are functions of the input current.

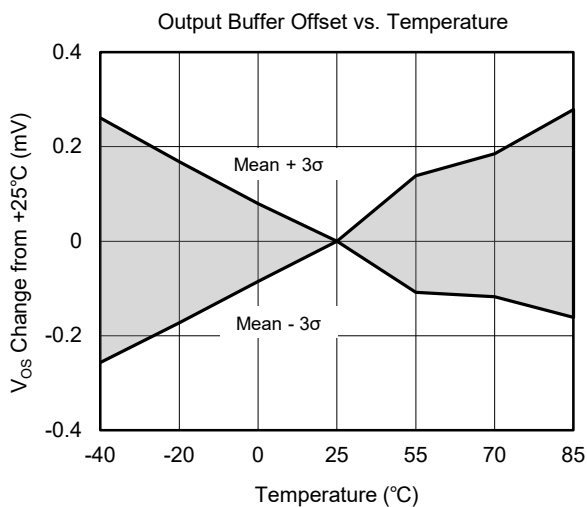
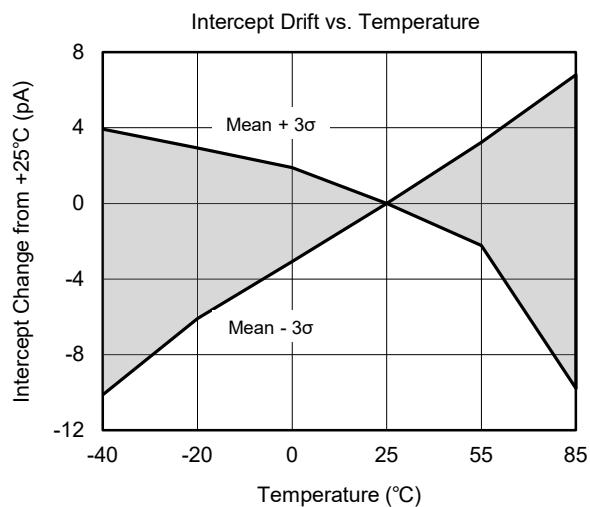
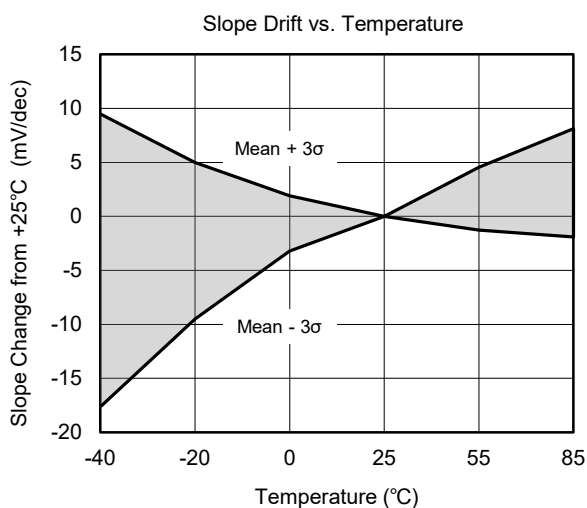
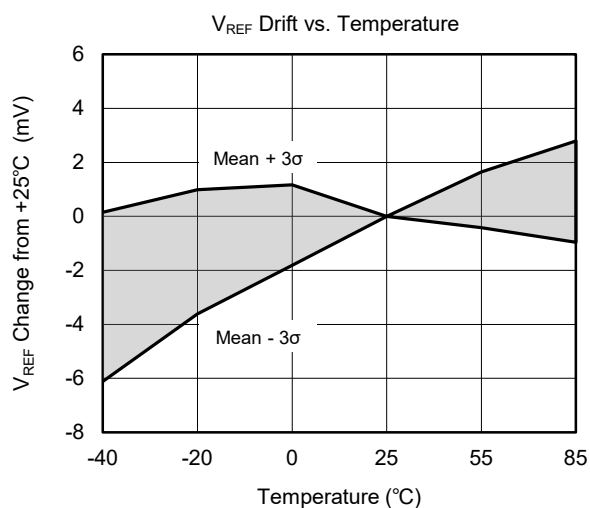
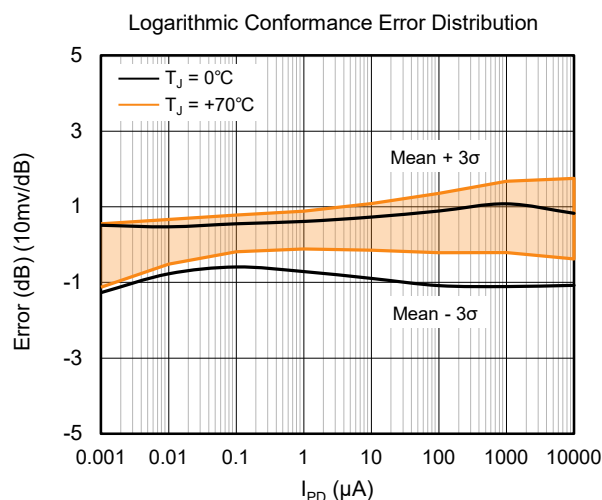
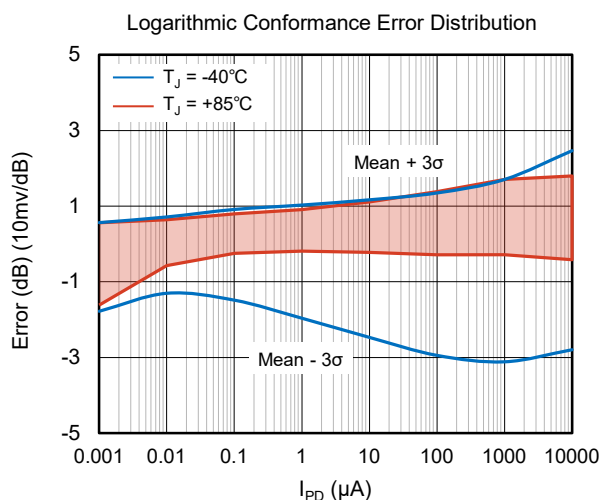
### TYPICAL PERFORMANCE CHARACTERISTICS

$T_J = +25^\circ\text{C}$  and  $V_P = 5\text{V}$ , unless otherwise noted.



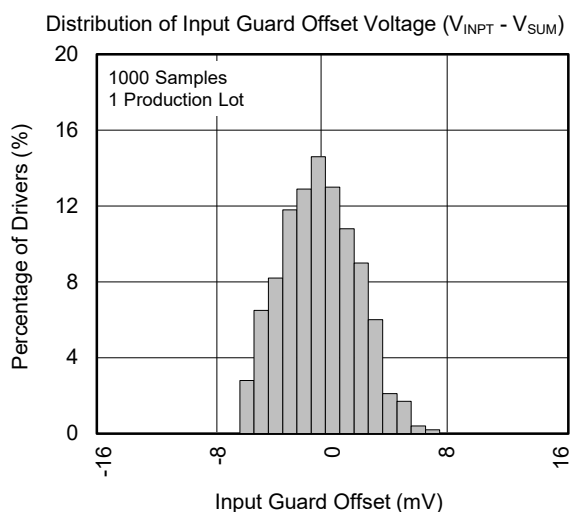
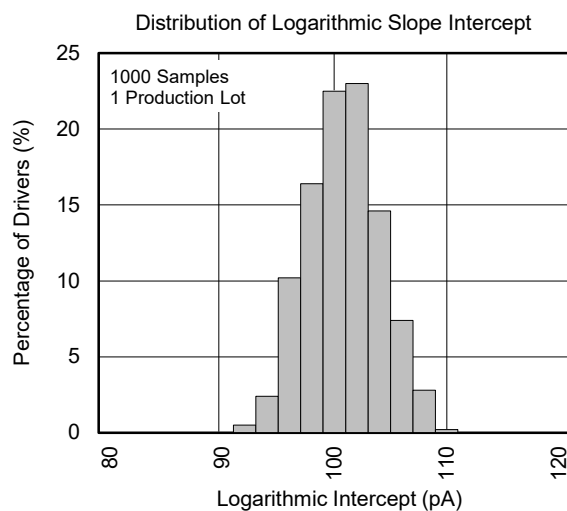
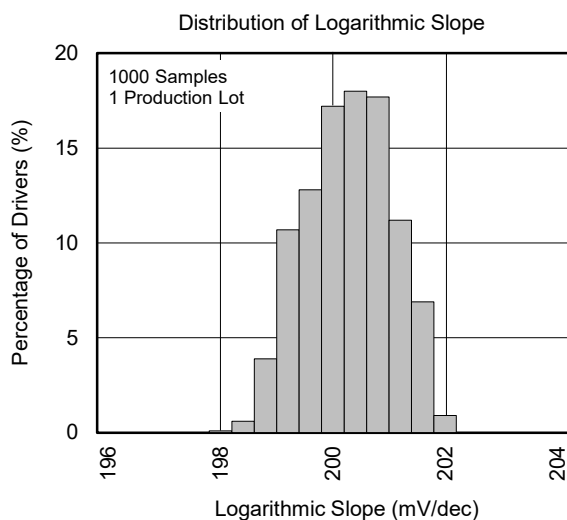
**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**
 $T_J = +25^\circ\text{C}$  and  $V_P = 5\text{V}$ , unless otherwise noted.


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## FUNCTIONAL BLOCK DIAGRAM

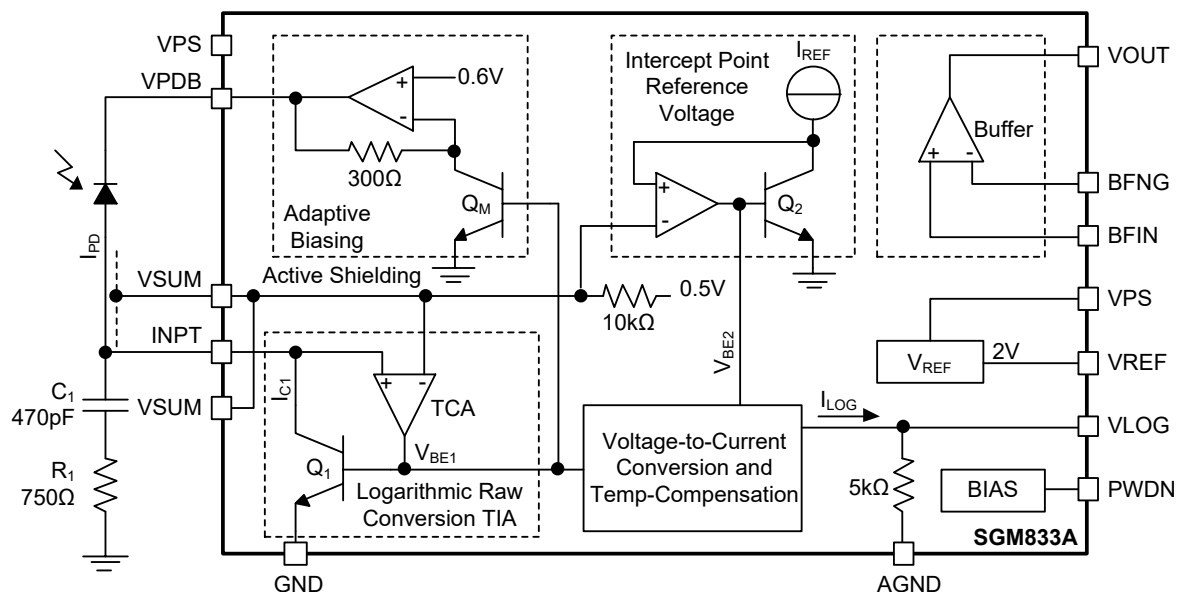
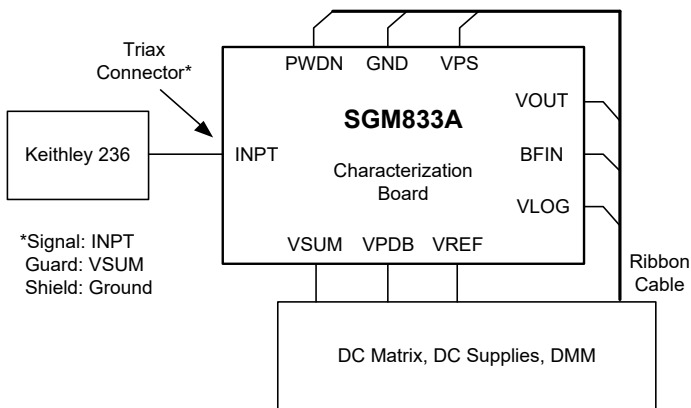


Figure 2. Functional Block Diagram

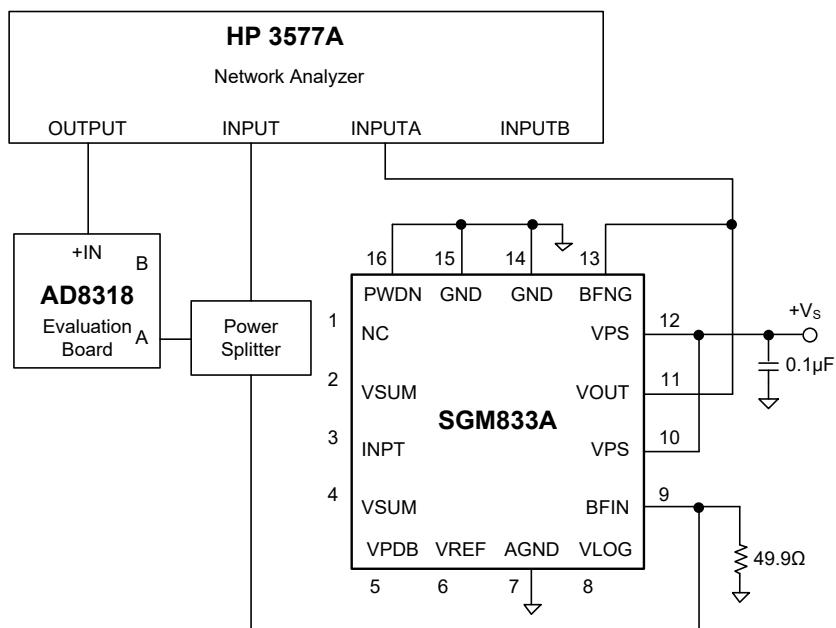
**SGM833A** **140dB Range (1nA to 10mA)**  
**Logarithmic Current-to-Voltage Converter**

## 140dB Range (1nA to 10mA) Logarithmic Current-to-Voltage Converter

## CHARACTERIZATION TEST SETUP



### Figure 3. Primary Characterization Setup



### Figure 4. Buffer Amplifier Bandwidth Measurement

## CHARACTERIZATION TEST SETUP (continued)

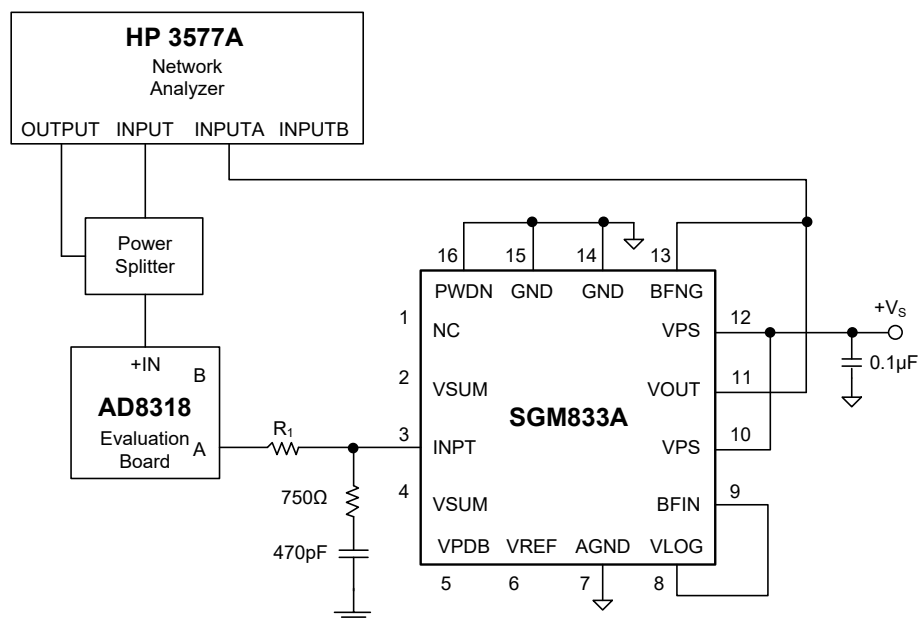


Figure 5. Converter Small Signal Bandwidth Measurement Setup

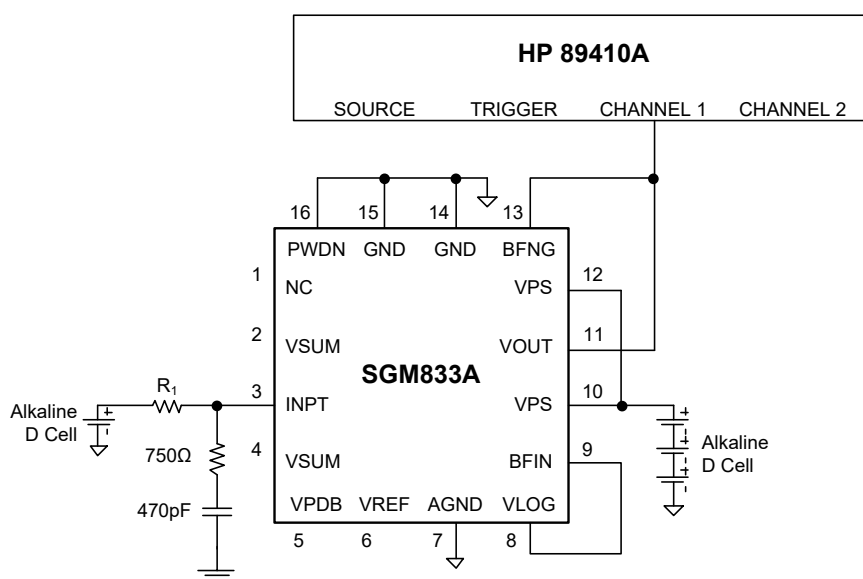


Figure 6. Noise Spectrum Measurement Setup

### DETAILED DESCRIPTION

#### Conversion Operating Principle

Figure 2 shows the block diagram of the SGM833A, including the logarithmic conversion blocks and the required compensations blocks for law conformance. The  $Q_1$  collector voltage is stabilized at 0.5V by a closed loop bias circuit. The 0.5V is an optimal voltage level for biasing the photodiode anode, and provides a good compromise between the diode ohmic leakage current errors that are significant at lower currents and the diode series resistance errors that are significant at higher currents. The adaptive bias block tries to keep the reverse bias across the diode junction to almost stable 0.1V by increasing the bias voltage at higher  $I_{PD}$  currents to compensate the diode bulk resistive drops. The inherent relationship of the collector current ( $I_C$ ) and the base-emitter voltage ( $V_{BE}$ ) in a bipolar transistor (like  $Q_1$ ) is expressed as:

$$V_{BE} = V_T \times \log_e(I_C/I_S) \quad (1)$$

$$V_T = kT/q \quad (2)$$

where:

$I_S$  is the saturation current of the transistor,  
 $\log_e$  is the natural logarithm operator,  
 $V_T$  is the thermal voltage,  
 $k$  is the Boltzmann constant ( $\sim 1.38 \times 10^{-23}$  J/K),  
 $T$  is the absolute temperature in Kelvin (K),  
 $q$  is the electron charge in Coulomb ( $\sim 1.6 \times 10^{-19}$  C).

Equation 1 provides the raw logarithmic principle that is used to convert the diode  $I_{PD}$  current flowing in the  $Q_1$  collector to the logarithmic voltage  $V_{BE1}$ . Note that the fundamental relationship between  $V_{BE}$  and  $I_C$  can be scaled by both  $I_S$  and  $V_T$ . The  $I_C = I_S$  determines the  $V_{BE} = 0$  intercept point. The  $I_S$  and the intercept point are highly temperature and process dependent and have to be compensated such that the output is independent of the  $I_S$  and  $T$ . To compensate the  $I_S$  variations, an identical dummy transistor ( $Q_2$ ) with the same geometrics and process as  $Q_1$  is implemented in the device to generate the reference voltage ( $V_{BE2}$ ) for the intercept point by setting its collector current to an stable and accurate reference current ( $I_{REF}$ ). The  $I_{REF}$  has an input referenced equalization stabilized around 1 $\mu$ A that is 10000 times higher than the intercept current ( $I_Z = 100$ pA typical).

Because  $Q_1$  and  $Q_2$  have the same saturation currents

and temperature dependence, the  $V_{BE1} - V_{BE2}$  is temperature and process independent at the intercept point (note that  $I_{REF}/I_Z$  is a constant).

$$V_{BE1} - V_{BE2} = kT/q \times \log_e(I_{PD}/I_{REF}) \quad (3)$$

However, at other currents, the relationship of  $V_{BE1} - V_{BE2}$  to  $I_C$  is still temperature dependent by a direct multiplication factor (proportional to  $T$ ). A current mirror multiplier and a voltage to current conversion multiplier are used to compensate the temperature variations and to convert the  $V_{BE1} - V_{BE2}$  voltage to a temperature and  $I_S$  independent current ( $I_{LOG}$ ). This current passes through an internal 5k $\Omega$  resistor for current to voltage conversion that provides the intermediate output voltage ( $V_{LOG} = 5k\Omega \times I_{LOG}$ ) with a fixed 200mV/dec typical slope (200mV increase per one decade or 10 $\times$  increase of  $I_{PD}$ ). The logarithmic conversion is represented by:

$$\begin{aligned} V_{LOG} &= 5k\Omega \times 40\mu A \times \log_{10}(I_{PD}/100pA) \\ &= 0.2V \times \log_{10}(I_{PD}/100pA) \end{aligned} \quad (4)$$

$$\frac{\log_{10}(x)}{\log_e(x)} \approx 0.4343 \quad (5)$$

$\log_{10}$  is more convenient than  $\log_e$  for per decade units used for the slope.  $I_Z = 100$ pA is the SGM833A intercept current.

#### Optical Power Measurement

The photodiode sensitivity defined by quantum efficiency is the number of electrons emitted as a result of the received photonic irradiation. Because the electron velocity is stable in a given electric field, the number of electrons (photo current) will be proportional to the incoming optical power. So, the  $I_{PD}$  can be measured and calibrated as an equivalent quantity with the optical power.

The logarithmic current to voltage conversion facilitates optical measurement in decibel scaling, in which the optical power is measured as a ratio to a given reference power, such as dBm that is the ratio to a 1mW reference. If the system is calibrated such that a 1mW optical power results in 1V output, then if a measurement reading is 1.2V, the optical power is calculated from  $200mV \times \log_{10}(P/1mW) = (1.2V - 1V)$  equation that results in  $P/1mW = 10$  or  $P = 10$ dBm.

**DETAILED DESCRIPTION (continued)****Available Output Range**

The low margin for the VLOG output for proper trimming and cancellation is limited (0.1V, TYP). So, when the actual input is very close to the intercept point ( $I_Z = 100\text{pA}$ ), the output is saturated to the low limit because VLOG cannot reach to zero. However, from almost a decade higher (1nA), the output is valid. The VLOG output impedance is 5k $\Omega$ . The adaptive biasing and compensation block are fully functional over the whole 3V to 5.5V supply range that helps in lowering the errors caused by diode resistive drops that could limit the effective high output range. The buffer amplifier provides a much smaller (0.1 $\Omega$ , TYP) output impedance. With a 1k $\Omega$  load, this output can swing up to  $V_P - 0.1\text{V}$ . If the output is near  $V_P - 0.1\text{V}$ , the law conformance might have been lost already, because it shows that the input current is above the guaranteed operating range.

**DC and AC Components**

The logarithmic conversion is valid for the steady state (settled DC) component of the input signal. The high frequency AC component of the  $I_{PD}$  should be filtered and blocked from entering into the INPT pin. Otherwise, large measurement errors are expected. Compared to the averaging before conversion, the signal averaging at the output of the converter adds much more error. For example, a 50% duty cycle input pulse signal with

$P_{PK}$  (dB) power peak, results in a realistic  $P_{PK} - 3\text{dB}$  average power if the signal is averaged before conversion. However, if the converter output is averaged, the result will be a meaningless average value of  $P_{PK}/2$  (dB) and also depends on 0dB reference.

**Bandwidth and Noise**

Even though the AC transfer function is meaningless for the nonlinear conversion circuit, the bandwidth data can help the evaluation of the output settling time. This is an important factor for reading and sampling the output with high accuracy and fast rate. The  $Q_1$  acts as a feedback path in the trans-impedance amplifier (TIA) conversion ( $I_{PD}$  to  $V_{BE}$ ). With low  $I_{PD}$  values, the trans-conductance (trans-linear) is very high and the loop gain is low that limits the bandwidth. It means the settling time will be long at low currents and short at higher currents due to the large variation of the loop gain. The bandwidth of TIA and the compensation network are both increased when the  $I_{PD}$  current goes high. It is necessary to stabilize the loop gain and the bandwidth. To this end, the external  $R_1$ - $C_1$  network is shunted with the  $Q_1$ . This will reduce the low current bandwidth even further. By using the buffer amplifier, the large bandwidth at higher currents is also limited by the buffer bandwidth.

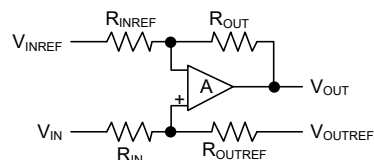
**DETAILED DESCRIPTION (continued)****Active Shielding and Adaptive Biasing**

The INPT voltage level is kept at 0.5V as shown in Figure 2. The same voltage is connected to VSUM pins that are located on the two sides of the INPT pin. It is recommended to surround the photodiode anode copper stripe that connects to the INPT pin, with the same voltage that is available on VSUM pins to minimize the  $I_{PD}$  leakage by creating a zero voltage difference between the INPT and the surrounding guard.

The  $Q_M$  is a current mirror to  $Q_1$  and its current is proportional to the  $Q_1$  current. The  $Q_M$  current flows into a current to voltage amplifier with a 0.6V offset to generate an adaptive bias for the photodiode. The photodiode bias increases from 100mV ( $= 0.6V - 0.5V$ ) minimum up to  $300mV/mA \times I_{PD} (mA)$ , or the headroom limit, whichever is less. The reverse bias voltage is increased at higher currents to compensate the resistive drops in the photodiode. Note that for higher range of the input current, the supply voltage needs to be high enough for proper operation of the adaptive bias. For example, with a 10mA input, the supply voltage must be at least 3.7V, otherwise the VPDB output will be saturated that may cause measurement error. An external bias can be applied to VSUM if the INPT voltage needs to be changed from 0.5V.

**The Reference and Buffer**

A 2V reference and a buffer operational amplifier (OPA) are integrated on the chip. The OPA can be used for VLOG conditioning or as a conventional op-amp or comparator.



**Figure 7. Re-scaling and Level-Shifting by an OPA**

Figure 7 shows how the buffer can be used to shift the  $V_{IN}$  signal that is referenced to  $V_{INREF}$  to a re-scaled  $V_{OUT}$  output signal referenced to the  $V_{OUTREF}$  voltage. The gain and level-shift are set by the four resistors.

**Chip Enable**

Pulling up the PWDN pin to logic high level will power down and disable the device. In this mode, the supply current drops to 9 $\mu$ A (TYP).

### APPLICATION INFORMATION

Shielding, guarding, filtering and proper diode biasing are critical factors to minimize the noise voltage coupled to the INPT, especially when the diode current is low and the feedback signal through  $Q_1$  is high. The diode resistive leakage (dark current) along with the multiplication and self-demodulation in the compensation multipliers can increase the errors significantly. Therefore, proper shielding, filtering and diode bias are essential before feeding the current signal for conversion.

Figure 8 shows how the parasitic leakage and  $R_1$ - $C_1$  network can cause delay in the negative feedback loop. It also shows how the active shielding loop provides positive feedback (bootstrap) at high  $I_{PD}$  currents by increasing the diode bias. The advantage of active shielding is insulating the INPT from ground leakage through the parasitic  $C_{PG}$  and  $R_{PG}$  elements and also from EMI pick-up. However, the penalty of shielding is larger parasitic  $C_{PS}$  that increases the delay in the

negative feedback loop. Setting the corner frequency of external  $R_1$ - $C_1$  network to smaller values will cause slower settling at lower  $I_{PD}$  currents but quicker settling at high currents. So the span of the desired operating range and the stability (or settling) of the converter need to be compromised depending on the application requirements.

Figure 9 shows some additional circuits for the photodiode bias and  $I_{PD}$  signal filtering. The  $C_{PDB}$ - $R_{PDB}$  low pass R-C network reduces the bandwidth of the adaptive biasing loop and helps the stability at high currents. The  $C_{PD}$ - $R_{PD}$  RC low pass filter network averages the  $I_{PD}$  before feeding it to the converter to suppress the error caused by the multiplication self-demodulation at low bit rate data communication applications.

Note that VLOG output filtering is not helpful for error suppression.

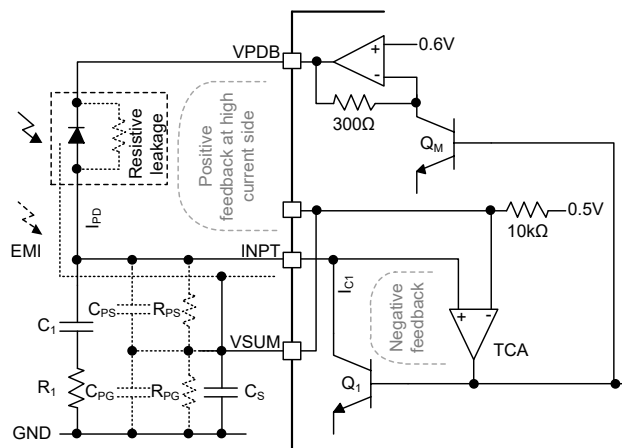


Figure 8. Conversion Loop and Active Shielding Loop

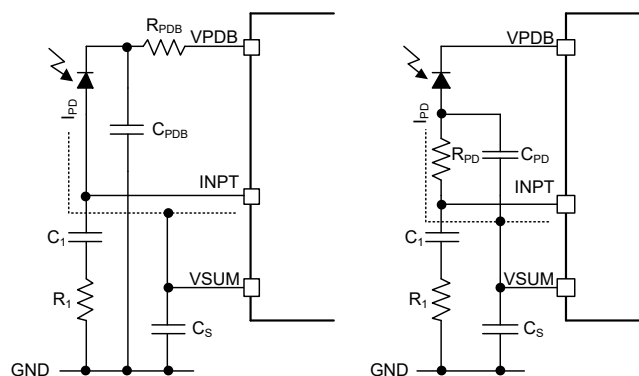


Figure 9. Filtering the VPDB and  $I_{PD}$



## APPLICATION INFORMATION (continued)

## VLOG Output Conditioning

The on-chip buffer amplifier and voltage reference can be used for adjusting the output intercept point and the scaling needed to match the desired signal level of the downstream process. Figure 10 shows the circuits that can be used for lowering or raising the intercept point.

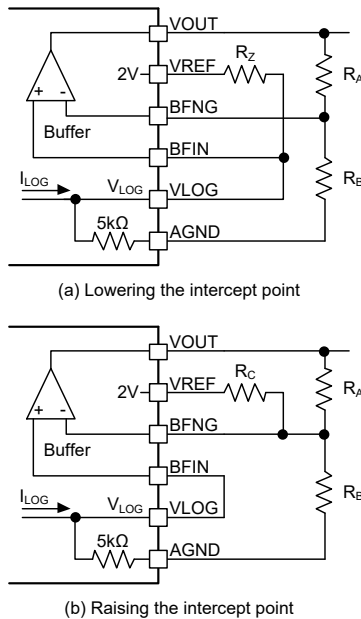


Figure 10. Adjusting the Intercept Point and Scaling

Table 1 lists some examples for selecting resistors for a few slope scales values while the intercept point is reduced from the  $I_Z = 100\text{pA}$ .  $V_Y$  in mV/dec is called the slope voltage.

Table 1. Some Examples of Lowering the Intercept Point

$V_Y$ (mV/dec)	$I_Z$ (pA)	$R_A$ (kΩ)	$R_B$ (kΩ)	$R_Z$ (kΩ)
200	1	20.0	100	25
200	10	10.0	100	50
200	50	3.01	100	165
300	1	10.0	12.4	25
300	10	8.06	12.4	50
300	50	6.65	12.4	165
400	1	11.5	8.2	25
400	10	9.76	8.2	50
400	50	8.66	8.2	165
500	1	16.5	8.2	25
500	10	14.3	8.2	50
500	50	13.0	8.2	165

The following equation can be used for calculating the resistors when a lower intercept point is desired:

$$V_{OUT} = G \left[ V_Y \times \frac{R_Z}{R_Z + R_{LOG}} \times \log_{10} \left( \frac{I_{PD}}{I_Z} \right) + V_{REF} \times \frac{R_{LOG}}{R_{LOG} + R_Z} \right] \quad (6)$$

where:  $G = 1 + \frac{R_A}{R_B}$  and  $R_{LOG} = 5\text{k}\Omega$ .

Usually it is more useful to raise the intercept point. Note that raising the intercept point reduces all output values. Figure 10 (b) shows how the intercept point is raised by placing the  $R_C$  between the BFNG and VREF pins. This arrangement raises the BFNG voltage (with zero input signal) and pushes the VOUT to lower values. Note that with the  $R_C$  connected to the BFNG pin, the gain ( $G$ ) is also affected, but it can be compensated and re-adjusted by  $R_A$  and  $R_B$ . Use the following equation for calculating the resistors (Figure 10 (b)):

$$V_{OUT} = G \left[ V_Y \times \log_{10} \left( \frac{I_{PD}}{I_Z} \right) - V_{REF} \times \frac{R_A \parallel R_B}{R_A \parallel R_B + R_C} \right] \quad (7)$$

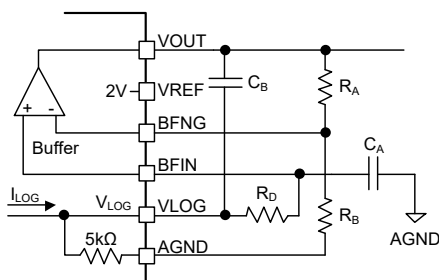
where:  $G = 1 + \frac{R_A}{R_B \parallel R_C}$  and  $R_A \parallel R_B = \frac{R_A \times R_B}{R_A + R_B}$ .

Table 2. Some Examples for Raising the Intercept

$V_Y$ (mV/dec)	$I_Z$ (nA)	$R_A$ (kΩ)	$R_B$ (kΩ)	$R_C$ (kΩ)
300	10	7.5	37.4	24.9
300	100	8.25	130	18.2
400	10	10	16.5	25.5
400	100	9.76	25.5	16.2
400	500	9.76	36.5	13.3
500	10	12.4	12.4	24.9
500	100	12.4	16.5	16.5
500	500	11.5	20.0	12.4

## 140dB Range (1nA to 10mA) Logarithmic Current-to-Voltage Converter

In most cases, a single-pole filter made by a capacitor ( $C_{FLT}$ ) between the VLOG and AGND works well for output filtering as shown in Figure 1. If a high-performance measurement system with lower noise is required, a slightly more complex filter such as a two-pole Sallen-Key filter can be used as shown in Figure 11. The precise 5k $\Omega$  source impedance is needed as a part of the Sallen-Key filter network (considering the Thevenin equivalent of the VLOG output).

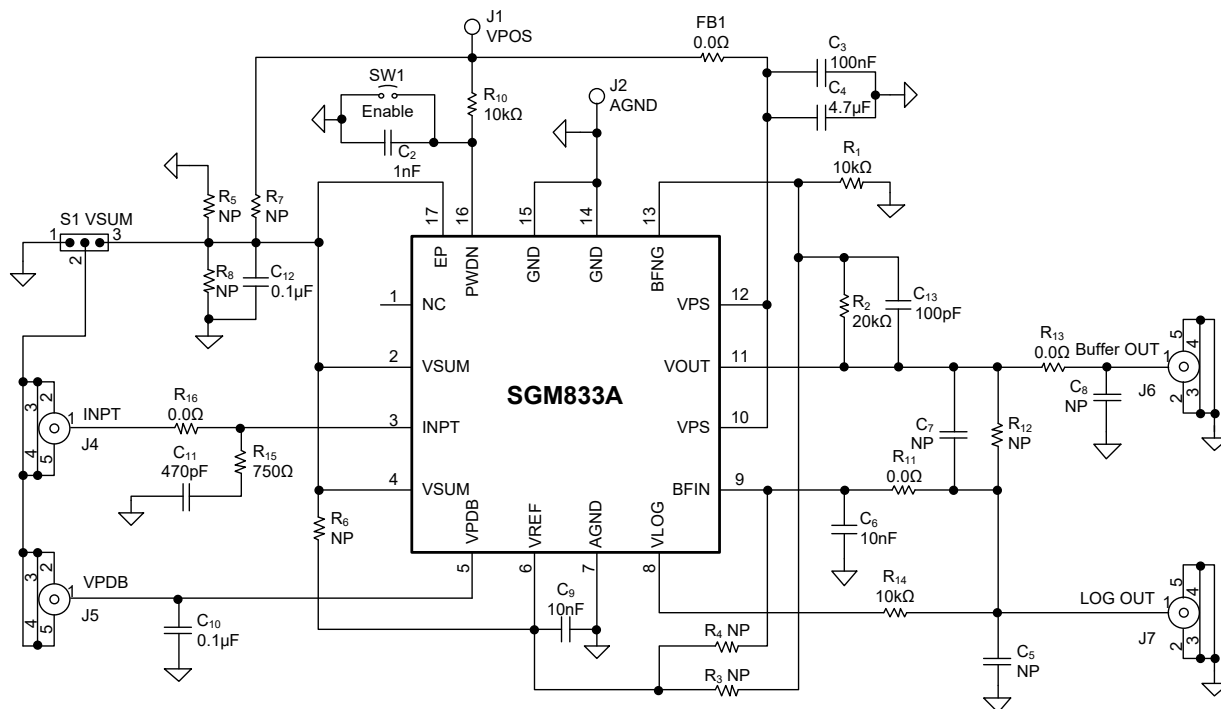


Some starting points for selecting the filter components for a few gain (G) examples and 1kHz cut-off frequency are provided in Table 3. The cut-off frequency can be increased or decreased by scaling the capacitor values.

The values of  $R_D$ ,  $G$ , and  $C_A/C_B$  ratio should not deviate from the suggested values in Table 3 to maintain the shape of the filter response.

$R_A$ (k $\Omega$ )	$R_B$ (k $\Omega$ )	G	$V_Y$ (V/dec)	$R_D$ (k $\Omega$ )	$C_A$ (nF)	$C_B$ (nF)
0	open	1	0.2	11.3	12	12
10	10	2	0.4	6.02	33	22
12	8	2.5	0.5	12.1	33	18
24	6	5	1.0	10.0	33	18

An evaluation board is available for the SGM833A with the schematic provided in Figure 12. The EVB can be configured for a wide variety of experiments. By default, the EVB is factory-set for a diode detector in photoconductive mode with a buffer gain of unity, 10mV/dB slope, and 100pA intercept point. By configuring the EVB resistors and capacitors, all application circuits and options presented in this datasheet can be evaluated as summarized in Table 4.



**Figure 12. SGM833A Evaluation Board Schematic**

## APPLICATION INFORMATION (continued)

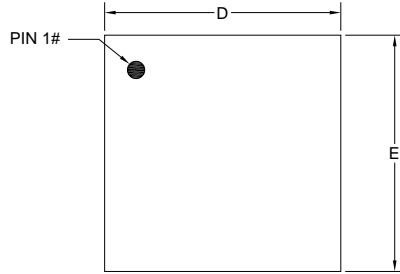
Table 4. Evaluation Board Configuration Options

Component	Function	Default Condition
VPOS, AGND	Positive Supply and Ground Pins.	NA
SW1, R <sub>10</sub>	Device Enable: With SW1 switch in the "0" position, the PWDN pin is grounded and the SGM833A operates in normal mode.	SW1 = Installed R <sub>10</sub> = 10kΩ
R <sub>1</sub> , R <sub>2</sub>	Buffer Amplifier Gain/Slope Adjustment: The logarithmic slope of the SGM833A can be changed by gain-setting resistors (R <sub>1</sub> and R <sub>2</sub> ) of the buffer amplifier.	R <sub>1</sub> = 10kΩ R <sub>2</sub> = 20kΩ
R <sub>3</sub> , R <sub>4</sub>	Intercept Adjustment: These resistors can apply DC offset to the buffer amplifier inputs to adjust the effective logarithmic intercept.	R <sub>3</sub> = NP
		R <sub>4</sub> = NP
R <sub>5</sub> , R <sub>6</sub> , R <sub>7</sub> , R <sub>8</sub>	Bias Adjustment: The VSUM and INPT voltages can be set by these resistors.	R <sub>5</sub> = R <sub>6</sub> = NP R <sub>7</sub> = R <sub>8</sub> = NP
C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> , C <sub>9</sub>	Power Supply, VREF and PWDN Decoupling Capacitors.	C <sub>2</sub> = 1nF C <sub>3</sub> = 0.1μF C <sub>4</sub> = 4.7μF C <sub>9</sub> = 10nF
C <sub>10</sub>	Photodiode Bias Output Decoupling Capacitor: Provides high frequency decoupling for the adaptive bias output at pin VPDB pin.	C <sub>10</sub> = 0.1μF
C <sub>12</sub>	VSUM Decoupling Capacitor.	C <sub>12</sub> = 0.1μF
C <sub>5</sub> , C <sub>6</sub> , C <sub>7</sub> , C <sub>8</sub> , R <sub>11</sub> , R <sub>12</sub> , R <sub>13</sub> , R <sub>14</sub>	Output Filter Configuration: These components can be used to implement a variety of filter configurations, from a simple low-pass RC filter to a three-pole Sallen-Key filter.	C <sub>5</sub> = NP C <sub>6</sub> = 10nF C <sub>7</sub> = C <sub>8</sub> = NP R <sub>11</sub> = R <sub>13</sub> = 0Ω R <sub>12</sub> = NP R <sub>14</sub> = 10kΩ
R <sub>15</sub> , C <sub>11</sub>	Input Filtering: This RC network sets the essential HF compensation at the input pin (INPT).	R <sub>15</sub> = 750Ω C <sub>11</sub> = 470pF
S1	Guard/Shield Options: The shells of the SMA input connectors for the photodiode and bias can be either connected to active shield driver on the VSUM pin or connected to ground.	S1 = Installed
C <sub>13</sub>	Feed-Forward Capacitor.	C <sub>13</sub> = 100pF
R <sub>16</sub>	Isolation Jumper.	R <sub>16</sub> = 0Ω

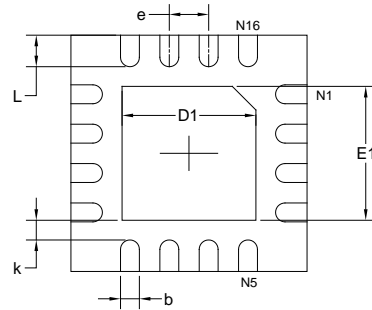
# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

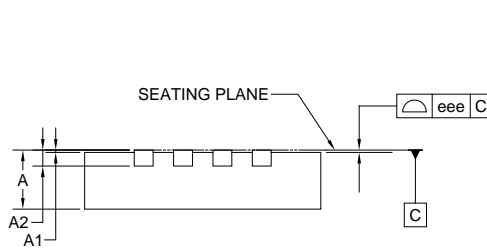
### TQFN-3x3-16L



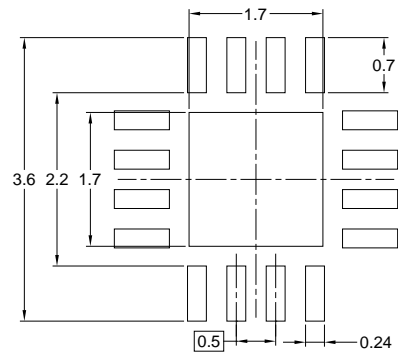
TOP VIEW



BOTTOM VIEW



SIDE VIEW



RECOMMENDED LAND PATTERN (Unit: mm)

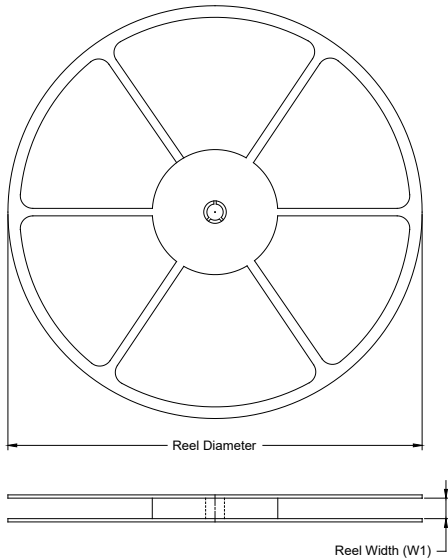
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.900	3.100	0.114	0.122
D1	1.600	1.800	0.063	0.071
E	2.900	3.100	0.114	0.122
E1	1.600	1.800	0.063	0.071
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.300	0.500	0.012	0.020
eee	0.080		0.003	

NOTE: This drawing is subject to change without notice.

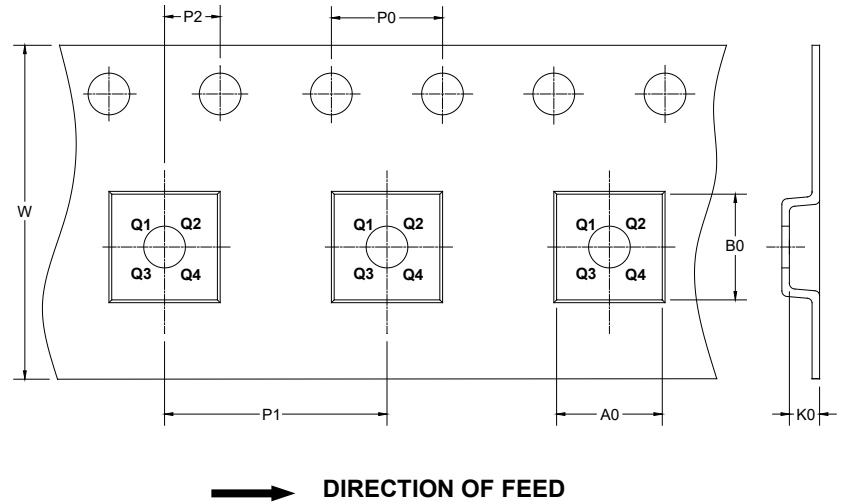
## PACKAGE INFORMATION

### TAPE AND REEL INFORMATION

#### REEL DIMENSIONS



#### TAPE DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

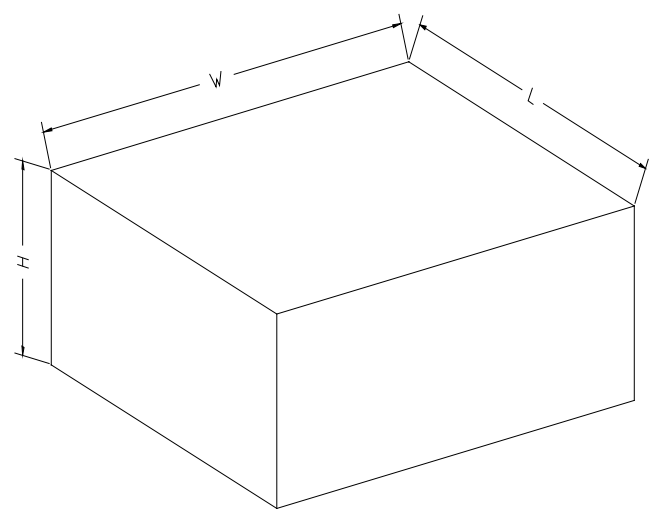
#### KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
TQFN-3×3-16L	13"	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q2

DD00001

# PACKAGE INFORMATION

## CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

## KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13"	386	280	370	5

DD0002