VITESSE

# VSC7979 Data Sheet

**SONET/SDH 12.5 Gbps High-Gain Transimpedance Amplifier**



## FEATURES

- 10 GHz bandwidth
- EDFA and fiber dispersion compensation
- High-gain 3 kΩ differential transimpedance eliminates need for post amplifier
- +3.3 V power supply
- 3 mAp-p maximum input current
- AC-coupled or DC-coupled outputs
- Photodetector average current monitor
- Low power: 182 mW
- Input sensitivity: –19 dBm typical
- Optical modulation amplitude (OMA) sensitivity consistent from 3 dB to 10 dB over extinction ratio

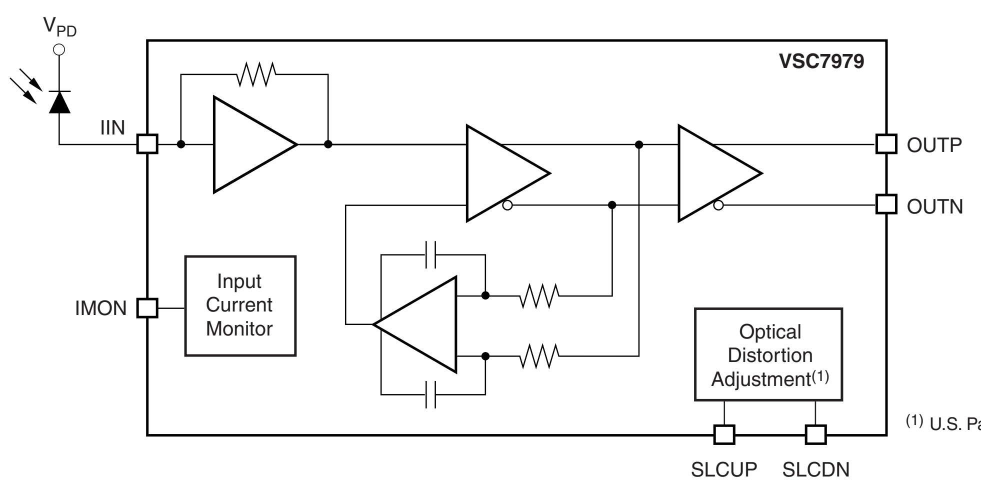
## APPLICATIONS

- Enterprise, Metro, and Long-Haul receiver optical sub-assembly modules
- Telecommunications transmission systems
- 9.953 Gbps SONET/SDH OC-192/STM-64
- 12.5 Gbps Forward Error Correction (FEC)
- 10.7 Gbps Optical Transport Network (OTN) transmission (G.709/G.975)
- 10.3 Gbps Ethernet
- 10.5 Gbps Fibre Channel
- XFP transceiver modules
- XENPAK, X2, XPAK, and 300-pin MSA transponder modules

## GENERAL DESCRIPTION

The VSC7979 is a 9.9 Gbps to 12.5 Gbps high-performance, low-power, transimpedance amplifier (TIA) that is ideal for use in optical communication networks. The VSC7979 is designed for use with a PIN photodetector or an Avalanche photodetector (APD). This device is capable of amplifying input currents of up to 4.5 mA typical, and down to 3 dB extinction ratio, with low duty-cycle distortion. The VSC7979 offers 3 kΩ differential transimpedance, eliminating the need for an additional post-amplifier. The outputs limit to a typical differential value of 600 mVp-p, increasing the dynamic range of the system by reducing the possibility of exceeding the input voltage range of the transceiver device. The VSC7979 optimizes optical sensitivity with special circuitry that compensates for high optical signal-to-noise ratio (OSNR) common in low-reach and wavelength division multiplexing (WDM) applications as a result of erbium-doped fiber amplification (EDFA) non-linearity and fiber dispersion.

### VSC7979 Block Diagram




(1) U.S. Patent Pending

# Functional Descriptions

The VSC7979 is a high-performance transimpedance amplifier designed for use in optical communication networks (SONET OC-192/SDH STM-64, 10 Gigabit Ethernet, 10 Gigabit Fibre Channel, OTN G.975 and G.709). It consists of a transimpedance stage, a limiting amplifier stage, and an output buffer stage. The total differential transimpedance gain is typically 3 kΩ .

The transimpedance stage accepts current from a photodetector connected to the input pin, IIN. A feedback resistor converts the current to voltage, and the limiting amplifier stage converts the single-ended signal to a differential signal. The data output, OUTP, goes HIGH (OUTN goes LOW) when light is applied to the external photodetector. For high input levels, the output limits are typically 600 mVp-p differential, which increases the dynamic range of the system by reducing the possibility of exceeding the input voltage range of the transceiver device

Figure 1 shows the relationship of single-ended output voltage versus input current. A DC restoration circuit in the limiting amplifier stage minimizes DC offset. The output buffer stage is capable of driving a 50 Ω single-ended load that can be either AC-coupled or DC-coupled to $V_{CC}$ with 50 Ω resistors.

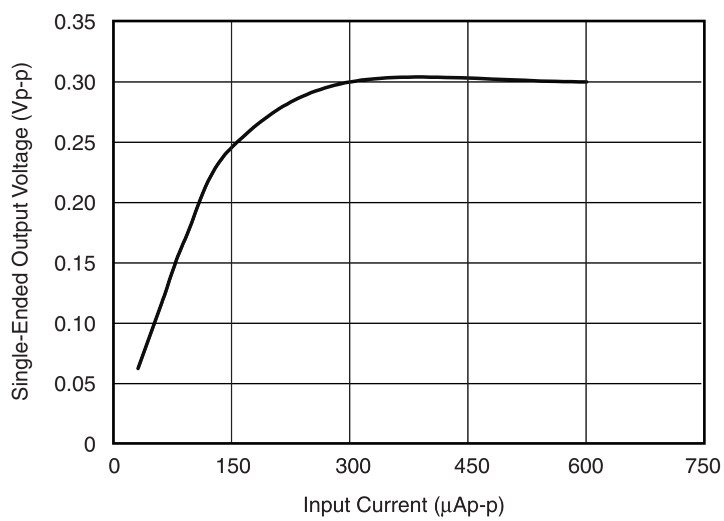



**Figure 1. Single-Ended Output Voltage vs. Input Current**

## Optical Distortion Adjustment

Optical communication systems have several types of impairments that can degrade system performance. These may include dispersion due to long spans of fiber, and noise introduced by optical nonlinearities and Amplified Spontaneous Emission (ASE) in an amplified optical system. The design of receivers in these optical systems may require special compensation techniques to optimize the bit error rate (BER).

The VSC7979 features an optional control function called optical distortion adjustment, which compensates for distorted input signals. The advantage of this feature is the capability to AC-couple the VSC7979 to the transceiver device while optimizing receiver optical sensitivity. The SLCUP and SLCDN pads control this function.

Figure 2 and Figure 3 show typical applications of the optical distortion adjustment feature.

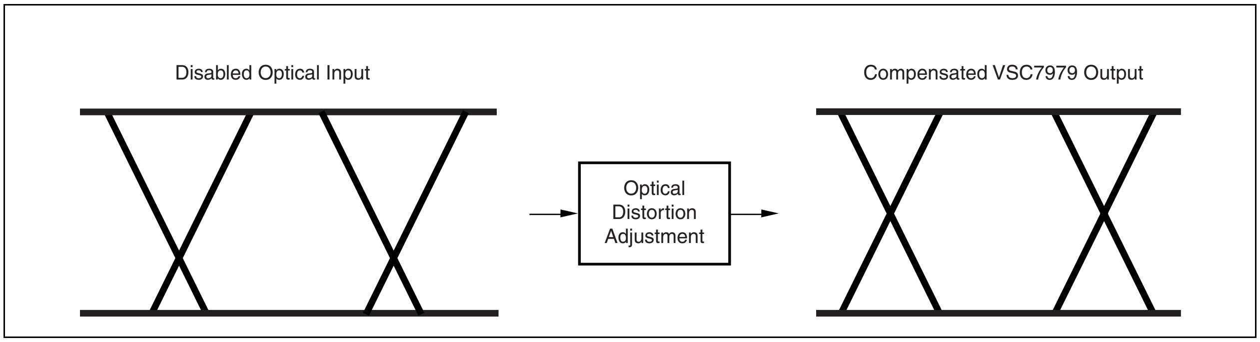



**Figure 2. Fiber Dispersion (single-ended)**

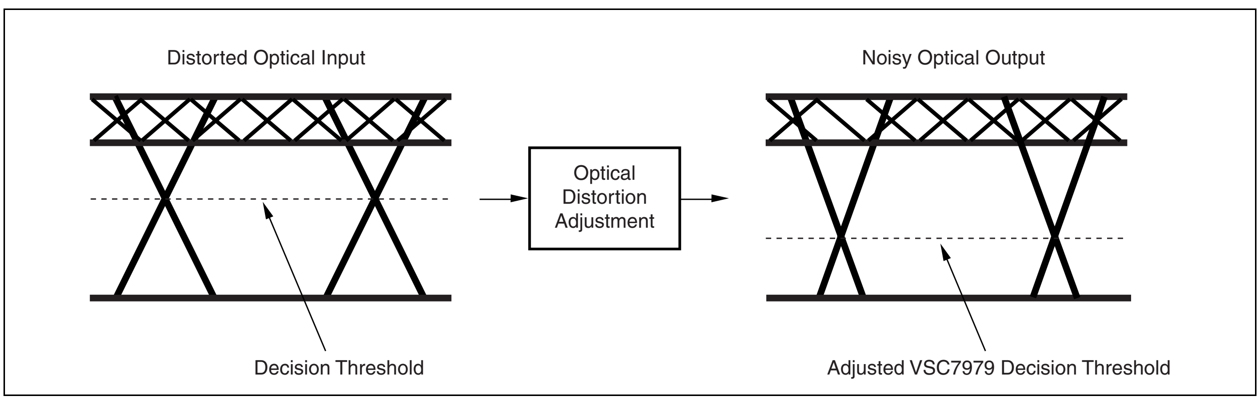



**Figure 3. Amplified Optical System (single-ended)**

The optical distortion adjustment feature is functional throughout the entire range of input currents to the VSC7979. The most effective operation, however, is achieved within the linear operating range of the VSC7979. Figure 4 illustrates the typical characteristics of this function at different input power levels.

If the optical distortion adjustment feature is not required, remove all connections to SLCUP and SLCDN and leave them floating; an internal DC restoration circuit automatically adjusts the DC voltage between OUTP and VOUT to 0 V. Alternately, if a resistive termination is desired, SLCUP and SCLDN may be tied to GND using 5 kΩ resistors. Capacitive termination is not recommended as it may result in oscillation. If capacitive termination is desired, connect SCLUP and SLCDN to GND using capacitors of less than 25 pF. Capacitors greater than 25 pF may result in oscillation.

Depending on the application, the distortion adjustment function can be controlled by varying the current through the SLCUP and SLCDN pins (the average current is 250 µA, with 1 V to 2 V bandgap for SLCUP and SLCDN). The graphs in Figure 4 and Figure 5 show typical characteristics of these control pins using a “1010…” pattern.

The output offset voltage is defined as the DC voltage of OUTP – OUTN. The graphs in Figure 4 and Figure 5 are generated by connecting a 5 kΩ resistor to one pin and adjusting the resistance on the other pin as shown in Figure 6.

The current can be adjusted by connecting a resistor network, as shown in Figure 6 or Figure 7, or by connecting another sink, such as a digital-to-analog converter (DAC) to SLCUP and SLCDN, as shown in Figure 8.

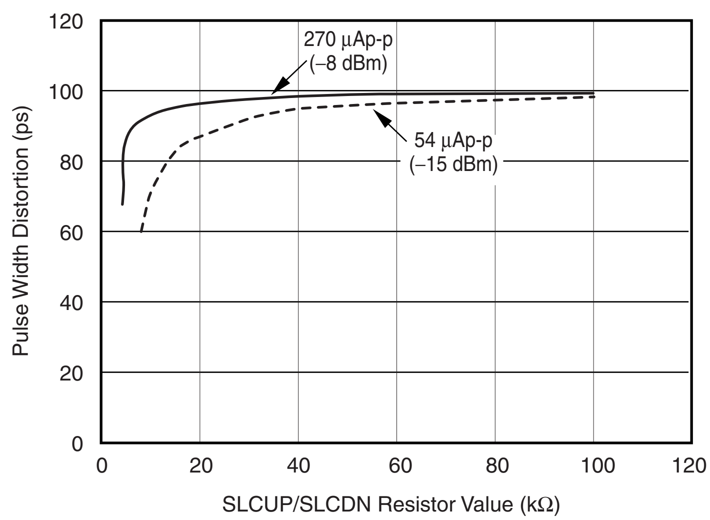



**Figure 4. Pulse Width Distortion vs. SLCUP and SLCDN Resistor Value**

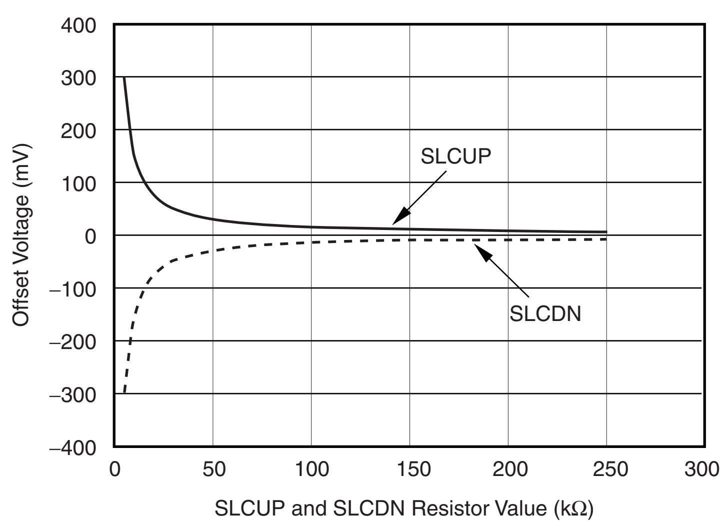
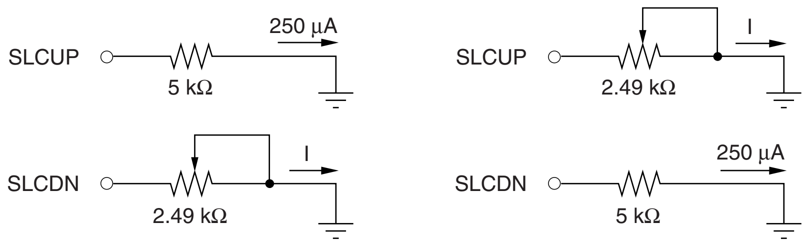


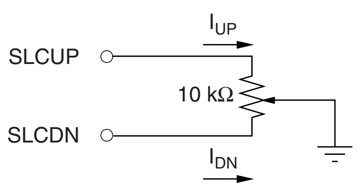

**Figure 5. Output Offset Voltage vs. SLCUP and SLCDN Resistor Value**

Figure 6 and Figure 7 show how to adjust the offset voltage with a potentiometer configured as a current source. Figure 8 shows how the offset voltage can also be adjusted using voltage drive with a DAC. This adjustment method is particularly useful in high SNR systems where Forward Error Correction (FEC) has been employed, as it provides feedback that can be used to dynamically tune the offset voltage.



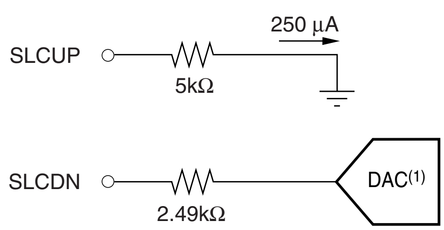

NOTE: Adjustment of the potentiometer varies the current (I) of SLCUP and SLCDN from 0 µA to 500 µA.

**Figure 6. Positive or Negative Current Sink Drive Offset**




NOTE: Adjustment of the potentiometer varies the current of SLCUP and SCLDN from 0 µA to 250 µA.

**Figure 7. Positive and Negative Current Sink Drive Offset**




(1) The voltage of the DAC should be adjustable from –0 V to 1.2 V
(±5% over temperature and power supply), with the maximum voltage not to exceed 1.2 V.

**Figure 8. Voltage Drive Offset**

## Photodetector Current Monitor

The IMON output provides a linear indication of the average input current from the photodetector to the transimpedance amplifier. See Figure 9. For example, if 20 µA is the average input current to the transimpedance amplifier, the current through the IMON pin is 20 µA. To use this feature, connect the IMON output to $V_{CC}$ using a resistor of less than 2 kΩ. If this feature is not used, leave IMON output unconnected.

The typical IMON offset current for zero current at the input is specified in Table 5 on page 10.

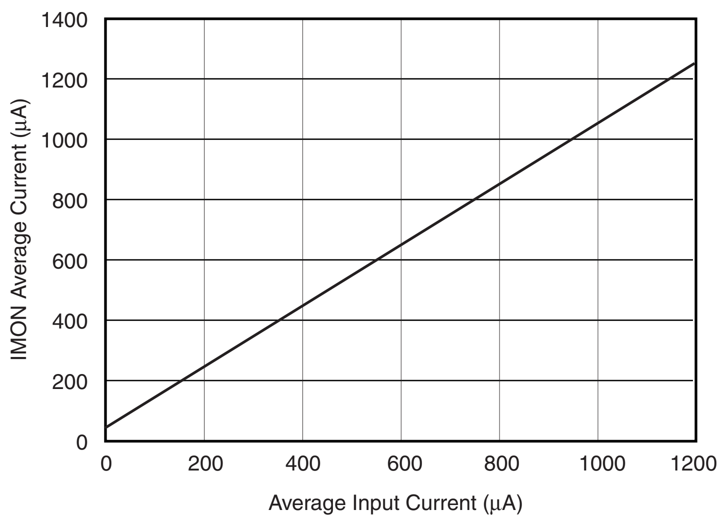



**Figure 9. IMON Current vs. Input Current**

## Power Supplies

A wideband power supply decoupling circuit is recommended between $V_{CC}$ and GND. The circuit should provide a low-impedance path between $V_{CC}$ and GND for frequencies between 30 kHz and 10 GHz.

To improve power supply rejection ratio (PSRR), use LC filtering at the supply. Place high-frequency decoupling capacitors as close as possible to the die. Low-frequency decoupling capacitors should also be placed near the die.

The VSC7979 has two power supply connections (VCC1 and VCC2) and one GND. All power supply and ground pads should be connected to maximize performance.

## Wire Bonding

For reliable operation, only gold wire bonds should be used. Depending on the application requirements, the frequency response of the VSC7979 can be optimized by varying the photodetector bond wire inductance. Generally, a longer bond wire increases bandwidth; however, increasing the bond wire excessively may affect other parameters (for example, group delay variation and peaking). The recommended photodetector bond wire inductance is 0.7 nH. All other bond wires should be kept as short as possible.

## Optical Sensitivity Calculation

Optical sensitivity is determined from the input-referred rms noise current, $I_N$. To achieve a bit error rate of $1E^{-12}$, the signal-to-noise ratio must be 14.1.

$$S = 10\log\left(\frac{SNR}{2} \times \frac{I_N}{\rho} \times \frac{r_e + 1}{r_e - 1} \times 1000\right) dBm \quad \text{(EQ 1)}$$

where,

$S$ = sensitivity (dBm)
$SNR$ = signal-to-noise ratio (dB)
$I_N$ = input-referred rms noise current (A)
$\rho$ = photodetector responsivity (A/W)
$r_e$ = extinction ratio (dB)

## Minimum Output Swing at Sensitivity Limit Calculation

The typical optical sensitivity is –19 dBm. At the input level, the voltage swing at the output of the VSC7999 is calculated as follows:

$$S_{AVG} = 10\log\left(\frac{OMA}{2} \times \frac{r_e + 1}{r_e - 1}\right) \quad \text{(EQ 2)}$$

where,

$S_{AVG}$ = average sensitivity (dBm)
$OMA$ = optical modulation amplitude (Wp-p)
$r_e$ = extinction ratio (dB)

# ELECTRICAL SPECIFICATIONS

## AC Characteristics

Table 1 lists specifications that are production tested in a 50 Ω probe environment and are guaranteed over the recommended operating conditions listed in Table 7. Certain parameters, such as bandwidth, are expected to improve when properly designed into the optical environment. See Table 2 for expected performance in an optical environment.

### Table 1. AC Characteristics for Bare Die in Probe Environment (VSC7979-W)

| Symbol | Parameter | Minimum | Typical(1) | Maximum | Unit | Condition |
|---|---|---|---|---|---|---|
| $Z_{T\_SE}$ | AC single-ended transimpedance gain(2) | 1000 | 1800 | 2500 | Ω | |
| $Z_{T\_DIFF}$ | AC differential transimpedance gain(2) | 2000 | 3600 | 4500 | Ω | |
| $BW_{TZ}$ | Transimpedance upper –3 dB bandwidth | 7.5 | 8.0 | 10 | GHz | At +25 °C. |
| $f_L$ | Lower –3 dB cutoff frequency | | 30 | 50 | kHz | With 0.1 µF AC-coupling capacitor at output. |
| $I_{PK\_MAX}$ | Maximum peak input current | 2.5 | 4.5 | | mA | $\varepsilon_r$ = 6 dB. |
| $I_{ND}$ | Input noise current | 1.3 | 1.5 | 1.9 | µA | At +25 °C. |
| $V_{OD}$ | Maximum differential output swing | 500 | 600 | 700 | mV | AC-coupled output, terminated to 50 Ω on each side, probe environment. |
| $V_{OS}$ | Maximum single-ended output swing | 250 | 300 | 350 | mV | AC-coupled output, terminated to 50 Ω on each side,probe environment. |
| $J_T$ | Peak-to-peak jitter | | 0.12 | 0.2 | UI | $PRBS^{31}$, 10.7 Gbps, 3 mA input current. |
| $I_{IN\_LINEAR}$ | Input linear range | | 120 | | µAp-p | See Figure 2. |
| $I_{IN\_LIM}$ | Input current for output limiting | 300 | 350 | 400 | µAp-p | See Figure 2. |
| $R_{OUT}$ | Output impedance | | 55 | | Ω | |
| $S_{22}$ | Output return loss | | –13 | –9 | dB | |

1. *Typical conditions of +35 °C at backside and +3.3 V supply.*
2. *The transimpedance gain is $Z_T = 50 \bullet S_{21} /(1- S_{11})$ at 500 MHz.*

The specifications listed in Table 2 are based on a photodetector with the following properties: photodetector capacitance ($C_{PD}$) = 0.2 pF, photodetector bond wire inductance ($L_{IN}$) = 0.7 nH, photodetector small signal bandwidth ($BW_{PD}$) = 15 GHz, referenced to 500 MHz. Effective bond wire inductance between detector cathode and decoupling capacitor (or $V_{PD}$) is 400 pH.

### Table 2. AC Characteristics for Optical Environment

| Symbol | Parameter | Typical(1) | Unit | Condition |
|---|---|---|---|---|
| $Z_{T\_SE}$ | AC single-ended transimpedance gain(2) | 1800 | Ω | 5 MHz. |
| $Z_{T\_DIFF}$ | AC differential transimpedance gain(2) | 3600 | Ω | 5 MHz. |
| $BW_{OPTICAL}$ | Minimum optical upper –3 dB bandwidth | 9.5 | GHz | Measured on optical characterization board at +25 °C. |
| $P_{OVERLOAD}$ | Maximum peak input optical power | 2 | dBm | Measured average power. |
| $S_{AVG}$ | Average optical sensitivity | –19 | dBm | R = 0.9 A/W, $r_e$ = 9 dB, BER $1E^{12}$. |
| $S_{OMA}$ | OMA optical sensitivity | –17 | dBm | R = 0.9 A/W, $r_e$ = 9 dB, BER $1E^{12}$. |
| $V_{OD}$ | Maximum differential output swing | 600 | mV | Measured peak-to-peak, AC-coupled output, terminated to 50 Ω on each side. |
| $V_{OS}$ | Maximum single-ended output swing | 300 | mV | Measured peak-to-peak, AC-coupled output, terminated to 50 Ω on each side. |
| $S_{22}$ | Output return loss | –10 | dB | 1 GHz to 6 GHz, bond wire inductance less than 587 pH. |
| Peak | Peaking | 0.8 | dB | 1 GHz to $f_{-3\ dB}$. |
| $t_{GD}$ | Group delay (peak-to-peak) deviation | 40 | ps | 1 GHz to $f_{-3\ dB}$. |
| $V_{SEN\_SE}$ | Single-ended output voltage at –19 dBm | 20.4 | mVp-p | |
| $V_{SEN\_DF}$ | Differential output voltage at –19 dBm | 40.8 | mVp-p | |
| PSRR | Power supply rejection ratio | –40 | dB | With π filter in the board. |

1. *Typical conditions of +35 °C at backside and +3.3 V supply.*
2. *The transimpedance gain is defined as $Z_T = V_{OUT(p-p)} / I_{IN(p-p)}$, where $V_{OUT}$ is the peak-to-peak output voltage and $I_{IN}$ is the peak-to-peak input current.*

# DC Characteristics

Specifications are guaranteed over the recommended operating conditions listed in Table 7.

### Table 3. DC Characteristics

| Symbol | Parameter | Minimum | Typical | Maximum | Unit | Condition |
|---|---|---|---|---|---|---|
| $V_{IN\_BIAS}$ | Input bias voltage | 0.8 | 0.9 | 0.95 | V | |
| $V_{OUT\_CM}$ | Output common-mode voltage | $V_{CC}$ – 0.70 | $V_{CC}$ – 0.35 | $V_{CC}$ – 0.05 | V | AC-coupled output, terminated to 50 Ω . |

### Table 4. Optical Distortion Adjustment

| Symbol | Parameter | Minimum | Typical | Maximum | Unit | Condition |
|---|---|---|---|---|---|---|
| $V_{OFFSET}$ | Adjustable output DC offset: $V_{OUTP} – V_{OUTN}$ | | 200 | | mV | |
| $R_{SLC\_RANGE}$ | Range of SLCUP/SLCDN resistor | 2500 | | | Ω | Parasitic capacitor at pins should be less than 25 pF. |
| $I_{SLC\_RANGE}$ | Range of SLCUP/SLCDN current | 0 | | 500 | µA | Parasitic capacitor at pins should be less than 25 pF. |
| $V_{OFFSET\_ACC}$ | $V_{OFFSET}$ accuracy | –40 | | +40 | mV | Part-to-part variation using a fixed resistor. |
| $R_{SLC}$ | SLCUP/SLCDN input impedance | | 200 | | Ω | |

### Table 5. Photodetector Current Monitor

| Symbol | Parameter | Minimum | Typical | Maximum | Unit | Condition |
|---|---|---|---|---|---|---|
| $I_{MON\_SLOPE}$ | Slope of $I_{MON}$ versus $I_{IN}$ | | 1 | | | |
| $I_{MON\_OFFSET}$ | $I_{MON}$ current at zero input current | 0 | 65 | 200 | µA | Average current. |

### Table 6. Recommended Photodetector Characteristics

| Symbol | Parameter | Minimum | Typical | Maximum | Unit |
|---|---|---|---|---|---|
| $C_{PD}$ | Photodetector capacitance | | 0.2 | | pF |
| $L_{PD}$ | Photodetector bond wire inductance | | 0.7 | | nH |
| $BW_{PD}$ | Photodetector –3 dB bandwidth | 12 | 15 | 20 | GHz |
| $R_{PD}$ | Photodetector resistance | 5 | 10 | 15 | Ω |

# Operating Conditions

### Table 7. Recommended Operating Conditions

| Symbol | Parameter | Minimum | Typical | Maximum | Unit |
|---|---|---|---|---|---|
| $V_{CC}$, $V_{CCP}$ | Power supply voltage | 3.0 | 3.3 | 3.6 | V |
| $I_{CC}$ | Power supply current | 40 | 55 | 60 | mA |
| $T_B$ | Die backside temperature | –10 | | +85 | °C |

# Maximum Ratings

### Table 8. Absolute Maximum Ratings

| Symbol | Parameter | Minimum | Maximum | Unit |
|---|---|---|---|---|
| $V_{CC}$, $V_{CCP}$ | Power supply voltage | 0 | 4 | V |
| $I_{IN}$ | DC input current | –2 | +5 | mA |
| $T_J$ | Junction temperature | –55 | +150 | °C |
| $T_S$ | Storage temperature | –55 | +150 | °C |
| $V_{ESD}$ | Electrostatic discharge voltage, human body model<br>Output pins (OUTP, OUTN)<br>Input pin (IIN)<br>All other pins | <br>–500<br>–200<br>–1000 | <br>+500<br>+200<br>+1000 | <br>V<br>V<br>V |

Stresses listed under Absolute Maximum Ratings may be applied to devices one at a time without causing permanent damage. Functionality at or above the values listed is not implied. Exposure to these values for extended periods may affect device reliability.

**ELECTROSTATIC DISCHARGE**

This device can be damaged by ESD. Vitesse recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures may adversely affect reliability of the device.

# APPLICATION EXAMPLES

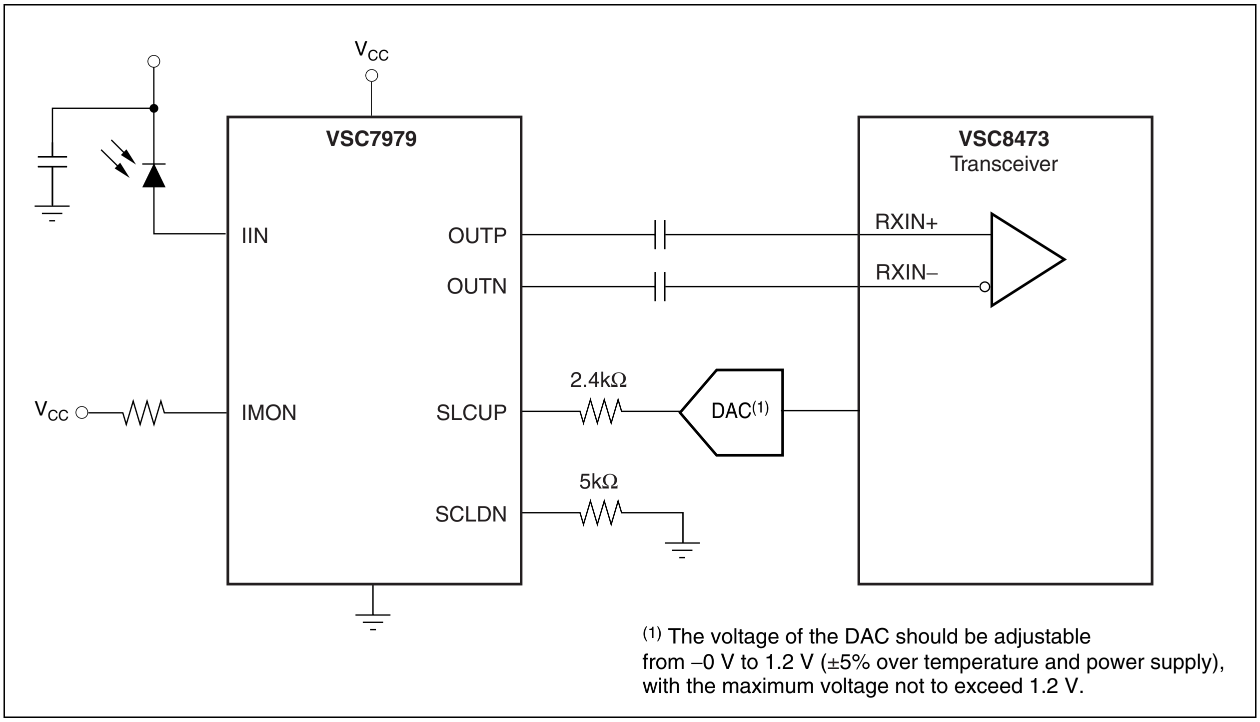



**Figure 10. Typical Application with Automatic Optical Distortion Adjustment**

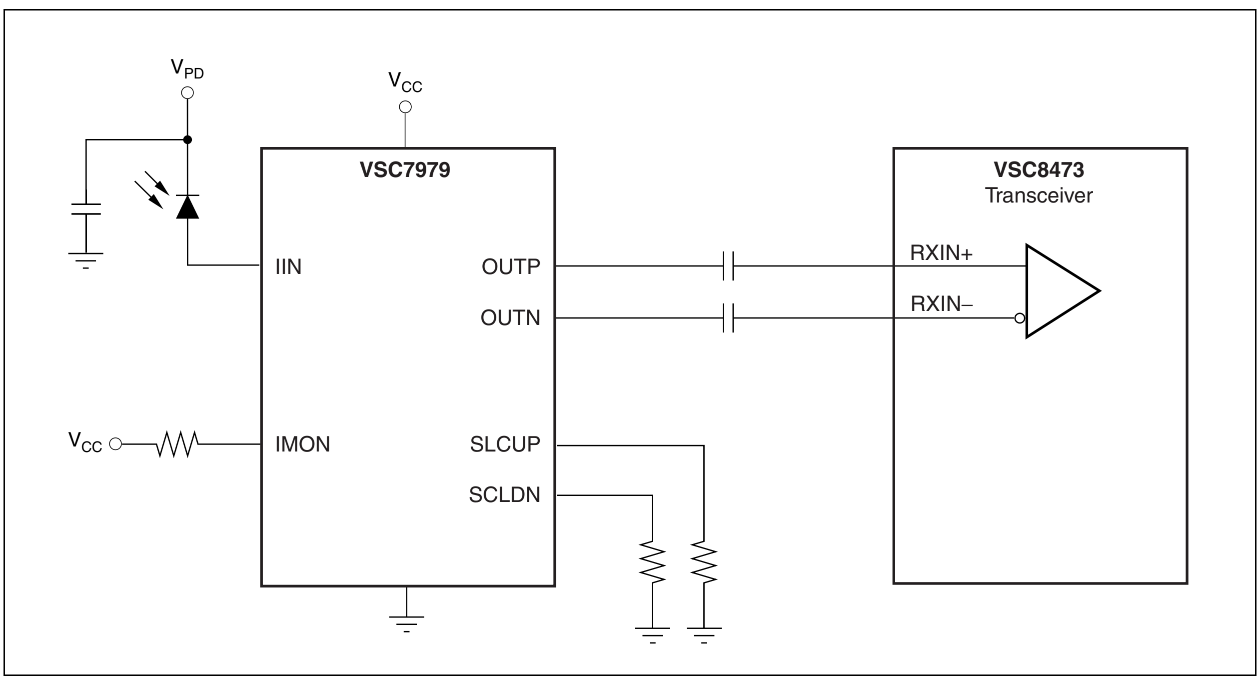



**Figure 11. Typical Application with Manual Optical Distortion Adjustment**

# DESIGN GUIDELINES

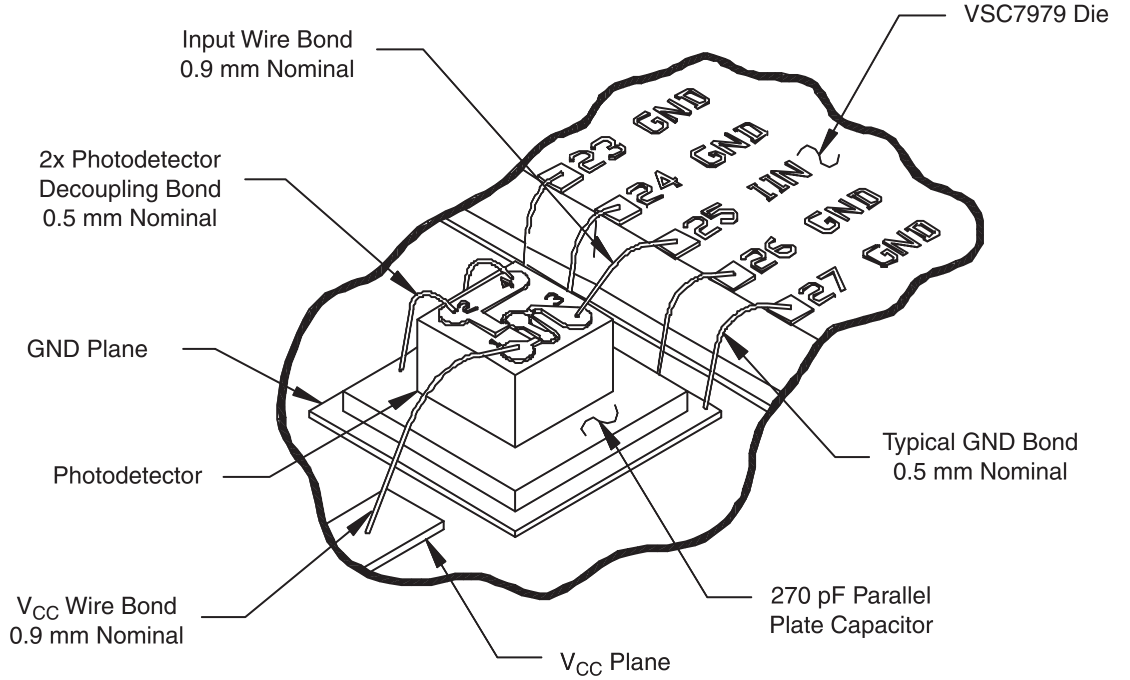
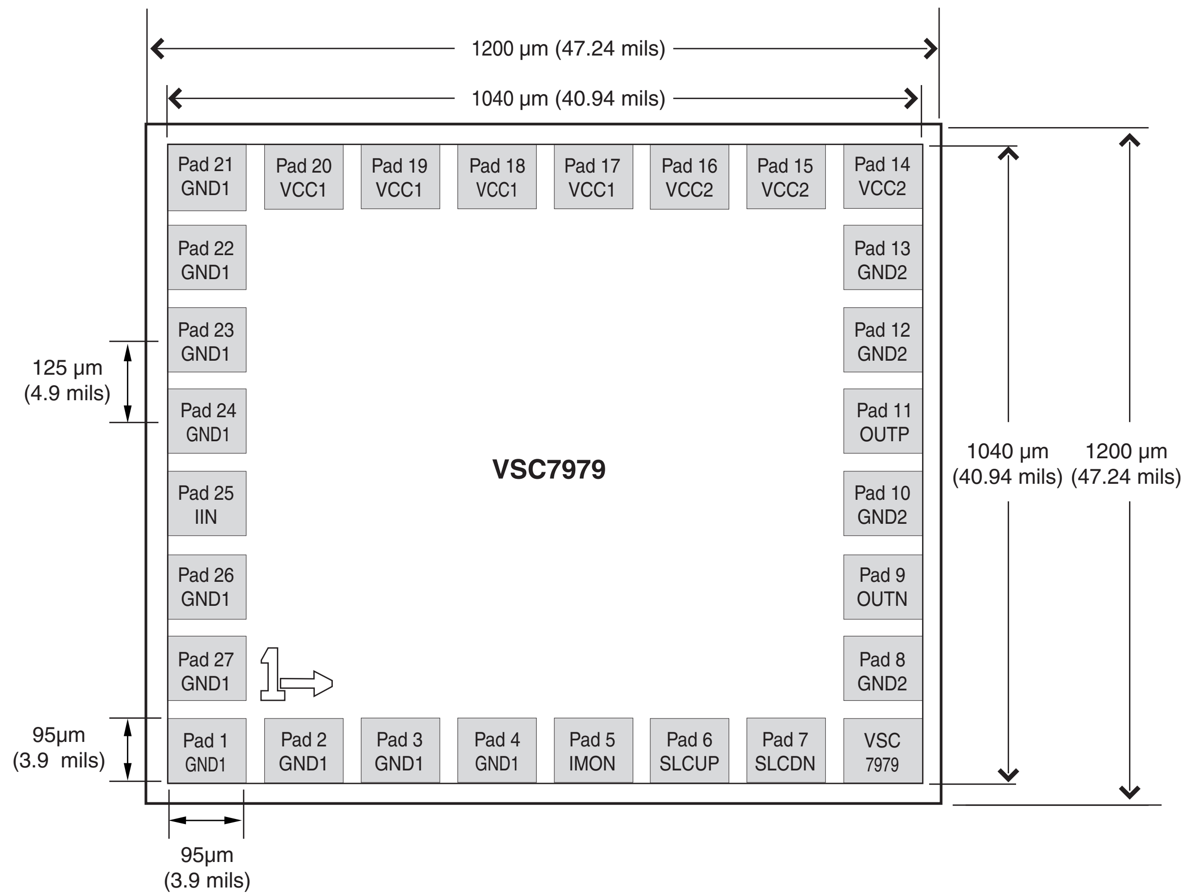



**Figure 12. VSC7979 Photodetector Wire Bonding Diagram**

# Bare Die Information

## Pad Diagram




| | |
|---|---|
| Max. Die Size Including Scribe: | 1200 µm x 1200 µm (47.24 mils x 47.24 mils) |
| Die Size Excluding Scribe: | 1040 µm x 1040 µm (40.94 mils x 40.94 mils) |
| Die Thickness: | 279 µm (11 mils) |
| Pad Size: | 95 µm x 95 µm (3.7 mils x 3.7 mils) |
| Pad Pitch: | 125 µm (4.9 mils) |
| Passivation Opening: | 80 µm x 75 µm (3.1 mils x 3.0 mils) |
| Passivation Opening for OUTN and OUTP: | 75 µm x 75 µm (3.0 mils x 3.0 mils) |

Die backside must be connected to the most negative supply.

**Figure 13. Bare Dice Pad Diagram**

# Pad Coordinates

### Table 9. Bare Die Pad Coordinates

| Signal Name | Pad Number | I/O | Level | Coordinates (µm) | | Description |
|---|---|---|---|---|---|---|
| | | | | X | Y | |
| GND1 | 1 | | Pwr | 74.78 | 81.98 | Ground. |
| GND1 | 2 | | Pwr | 206.98 | 70.18 | Ground. |
| GND1 | 3 | | Pwr | 331.98 | 70.18 | Ground. |
| GND1 | 4 | | Pwr | 456.98 | 70.18 | Ground. |
| IMON | 5 | O | | 581.98 | 70.18 | DC current proportional to photodetector input current. |
| SLCUP | 6 | O | | 706.98 | 70.18 | Positive voltage offset control. Connect resistor to ground. |
| SLCDN | 7 | O | | 831.98 | 70.18 | Negative voltage offset control. Connect resistor to ground. |
| GND2 | 8 | | Pwr | 965.24 | 206.98 | Ground. |
| OUTN | 9 | O | | 965.24 | 331.98 | Negative data output. |
| GND2 | 10 | | Pwr | 965.24 | 456.98 | Ground. |
| OUTP | 11 | O | | 965.24 | 581.98 | Positive data output (HIGH for optical input). |
| GND2 | 12 | | Pwr | 965.24 | 706.98 | Ground. |
| GND2 | 13 | | Pwr | 965.24 | 831.98 | Ground. |
| VCC2 | 14 | | Pwr | 965.24 | 956.98 | Power supply 2, +3.3 V. |
| VCC2 | 15 | | Pwr | 831.98 | 969.72 | Power supply 2, +3.3 V. |
| VCC2 | 16 | | Pwr | 706.98 | 969.72 | Power supply 2, +3.3 V. |
| VCC1 | 17 | | Pwr | 581.98 | 969.72 | Power supply 1, +3.3 V. |
| VCC1 | 18 | | Pwr | 456.98 | 969.72 | Power supply 1, +3.3 V. |
| VCC1 | 19 | | Pwr | 331.98 | 969.72 | Power supply 1, +3.3 V. |
| VCC1 | 20 | | Pwr | 206.98 | 969.72 | Power supply 1, +3.3 V. |
| GND1 | 21 | | Pwr | 74.78 | 956.98 | Ground. |
| GND1 | 22 | | Pwr | 74.78 | 831.98 | Ground. |
| GND1 | 23 | | Pwr | 74.78 | 706.98 | Ground. |
| GND1 | 24 | | Pwr | 74.78 | 581.98 | Ground. |
| IIN | 25 | I | | 74.78 | 456.98 | Photodetector input. |
| GND1 | 26 | | Pwr | 74.78 | 331.98 | Ground. |
| GND1 | 27 | | Pwr | 74.78 | 206.98 | Ground. |

***NOTE:*** *All GND1 pads are internally connected to each other, and all GND2 pads are internally connected to each other. It is required that both the GND1 and GND2 pads be connected to ground.*

# ORDERING INFORMATION

### VSC7979 SONET/SDH 12.5 Gbps High-Gain Transimpedance Amplifier

| Part Number | Description |
|---|---|
| VSC7979-W-01 | Bare dice, waffle pack |



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