EVM User's Guide: OPA598EVM

OPA598 Evaluation Module

Description

This user's guide describes the operation and use of the OPA598EVM evaluation module (EVM). The user's guide provides information on how to set up the EVM and describes different circuit configurations that may be used to fully evaluate the performance of the OPA598 high-voltage (HV), high-current (HI) op amp. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the OPA598EVM. This document also includes an electrical schematic, simplified schematics of OPA598 applications circuits, a printed circuit board (PCB) layout drawing, and a parts list for the EVM.

Get Started

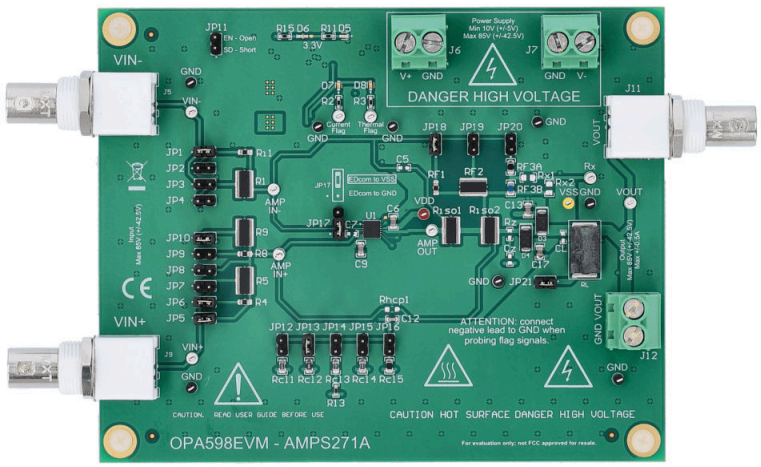
1. Order the OPA598EVM from the tool page
2. Review OPA598 data sheet for detailed device specification
3. Connect power, input signals, and output equipment

Features

- Various configuration options: Inverting, non-inverting, V-to-I converter
- Adjustable current limit via jumper shunts
- Preconfigured gain selection via jumper selection
- Thermal shutdown LED indicator
- LED indicator for current limited operation

Applications

- Semiconductor test
- Semiconductor manufacturing
- Programmable DC power supply
- LCD test
- CT and PET scanner



EVM Board Photo

1 Overview

The OPA598 is a high-voltage, high-current operational amplifier (op amp) applicable to a wide range of industrial and commercial applications. The device is functionally similar to low-power operational amplifiers, but with the added ability to provide upwards to 300 mA of output current while being powered by a supply voltage as high as ±42.5 V (85 V). Thermal shutdown protection, accurate current limiting, and an enable-shutdown feature allow for maximum application versatility.

This evaluation module (EVM) has been developed specifically for the OPA598, allowing users to more easily evaluate their circuit ideas and design concepts. The device has been designed for use with future HV-HI op amps similar to the OPA598 that will use the same package and pin functions and are electrically similar. Applying some imagination, the EVM PCB layout and footprints can accommodate variations on these circuit designs.

The OPA598EVM can be easily configured as a noninverting amplifier, inverting amplifier, difference amplifier, or as an improved Howland current pump (V-to-I converter) with this EVM. The user's circuit is realized on a 13.4-cm wide × 10.8-cm long × 3.2-cm tall PCB assembly that accommodates the OPA598DNT in a 12-lead, 4-mm × 4-mm, SON (12) package. The EVM PCB top, internal and bottom copper patterns, beneath and extending outward from the package are optimized as an effective heat sink. The board design transfers heat from the op amp to the surrounding copper and then to the air, helping cool the op amp die.

The OPA598EVM is powered from either a single supply, or dual supplies with a range from ±5 V (10 V) to ±42.5 V (85 V). Adding a short wire between the two screw terminals of J7 sets up the single-supply ground, while J6 is used for V+. For dual-supply operation, use J6 (V+) for the positive connection, J7 (V–) for the negative connection, and either GND or both GND screw terminals for the ground-return connection.

A green LED illuminates when V+ is applied to ground. The OPA598 enable-shutdown function and the thermal and current flag pullup circuits are powered from two onboard, high-voltage linear regulators (TPS7A4333). The regulator output is set to 3.3 V relative to the referenced ground, or common. These onboard regulators eliminate the need for external low-voltage supplies.

The enable-shutdown function and thermal shutdown indicator are functional with either supply configuration. A yellow LED, D6, illuminates when the amplifier is set to shutdown mode (low-current, output-disabled mode). An orange LED, D7, illuminates when the OPA598 is forced into current-limit mode. The red LED, D8, illuminates when the amplifier goes into thermal shutdown. During normal OPA598 operating conditions, the D6, D7, and D8 LEDS are expected to be off.

1.1 Getting Started

The OPA598EVM is powered from a 10-V to 85-V single supply, or ±5-V to ±42.5-V dual supply. The external power supply used to power the EVM must be capable of supplying the total anticipated current required by the particular OPA598 circuit configuration and the load. The OPA598 can supply a dc or peak output current approaching ±300 mA. Use a power supply capable of providing at least 2x the anticipated continuous current to account for peak-current conditions. Make sure any cables used with the EVM are rated to carry the high current, and sustain voltages of 100 V or more.

The input to the EVM can be a dc source, an ac signal source such as signal generator, or the actual signal derived from a sensor or transducer. A jumper shunt can be placed across JP10 that connects a 49.9-Ω, 2-W termination resistor from the VIN+ input (J9) input to ground. This internal resistor provides a handy input instrument termination impedance very close to 50 Ω.

Other resistors on the EVM that may have to dissipate high power are laid out with the wide 2512, 2-W footprint. If the EVM is set up to use different, higher-resistance resistors, the 2-W resistors can be desoldered and removed. A 0805 footprint is incorporated within each of the larger wide 2512 resistor board patterns. These are in addition to the other 0805 footprints available for use as input and feedback resistors.

Output signals derived from the EVM can be monitored by whatever means available to the user. Often, an oscilloscope with a 10x probe provides a good way to observe the output waveform from the OPA598 output (VOUT). The output signal VOUT is connected to the J11 BNC connector that is intended for the instrument connection. Additionally, VOUT is brought to high-voltage terminal block J12. The block may be used to connect the output load to the OPA598 output. The load may be a resistor, motor, actuator, power transducer, or an active load.

Some OPA598 output loads dissipate moderate power and some may be physically large. In this case, the load can be located external to the EVM PCB.

1.1.1 Related Documentation From Texas Instruments

Document	Literature Number
OPA598 product data sheet	SBOSAA7

1.2 High-Voltage Warning and Safe Use

As previously mentioned, the OPA598 op amp can use a power-supply voltage as high as 85 V in a single-supply connection, or ±42.5 V in a dual-supply connection. Both supply conditions represent a potential difference of 85 V. Voltage potential differences of 50 V or greater are potentially lethal to humans and must be treated with a higher level of caution and awareness than when working with low voltages. Consult your company's established high-voltage *best practices* and follow them when using this EVM. Do not leave the EVM unattended when high-voltage is present.

Additionally, keep in mind that the OPA598 is a power op amp. The OPA598 and the output load can generate enough heat to become hot to the touch under some operating conditions. Exercise caution when working with the EVM to avoid physical contact with the OPA598 and the load that the device may be driving in case either become hot.

1.3 Electrostatic Discharge Caution

Some of the OPA598EVM components can be susceptible to electrostatic discharge (ESD) damage. Customers are advised to observe proper ESD handling precautions when unpacking and handling the EVM outside the supplied ESD safe bag and shipment container.

CAUTION

A grounded wrist strap should be worn by the EVM handler at an ESD safe workstation. However, an ESD wrist strap may only be used when circuit voltages are less than 100 V. *Do not wear an ESD wrist strap if the potential difference is ≥ 100 V*. For circuit voltages ≥100 V, apply an ionizer for ESD control.

2 Hardware

This section describes the circuitry and operation of the OPA598EVM.

2.1 Jumper Blocks, Jacks, and Test Points

The OPA598EVM includes a variety of jumper blocks, jacks, and test points that allow the EVM to be configured and evaluated in several circuit, test, and power supply configurations. The following provide the jumper block, jack, or test point number, and a brief description.

Table 2-1 lists the jumper block connections. See Figure 4-1 and Figure 4-3 for jumper block locations.

Table 2-1. Jumper Block Connections

Jumper Block	Connection When Jumper Shunt Installed Across Jumper Block
JP1	Ri1 (10 kΩ) from VIN– jack J5 to OPA598 –IN pin
JP2	Ri1 (10 kΩ) input end to GND
JP3	Ri1 (1 kΩ, 2 W) from VIN– jack J5 to OPA598 –IN pin
JP4	Ri1 (10 kΩ) input end to GND
JP5	VIN+ jack J9 to OPA598 +IN pin
JP6	VIN+ jack J9 to OPA598 +IN through R4 (10 kΩ)
JP7	VIN+ jack J9 to OPA598 +IN through R5 (1 kΩ, 2 W)
JP8	OPA598 IN+ pin to GND
JP9	R8 (10 kΩ) from OPA598 +IN pin to GND
JP10	R9 (49.9 Ω, 2 W) from OPA598 +IN pin to GND
JP11	OPA598 in shutdown (SD) mode
JP12	Rcl1 (237 kΩ) to GND sets the short-circuit current to 50 mA
JP13	Rcl2 (90.9 kΩ) to GND sets the short-circuit current to 100 mA
JP14	Rcl3 + R13 (41.2 kΩ + 422 Ω) to GND sets the short-circuit current to 150 mA
JP15	Rcl4 (16.9 kΩ) to GND and sets the short-circuit current to 200 mA
JP16	Rcl5 (2.32 kΩ) to GND sets the short-circuit current to 250 mA
JP17	Two of 3 pins used to reference EDcom to either VSS or GND
JP18	RF1 (10 kΩ) in OPA598 feedback path
JP19	RF2 (1 kΩ, 2 W) in OPA598 feedback path
JP20	RF3A, RF3B, Rx1, Rx2 network in OPA598 feedback path
JP21	RL (1 kΩ, 2 W) resistor to ground

Table 2-2 lists the jack functions. See Figure 4-1 and Figure 4-3 for jack locations.

Table 2-2. Jack Functions

Jack	Function
J1	NA
J2	NA
J3	NA
J4	NA
J5	OPA598 VIN- input, BNC female connector
J6	V+ power supply and GND terminal block (screw type)
J7	V- power supply and GND terminal block (screw type)
J8	NA
J9	OPA598 VIN+ input, BNC female connector
J10	NA
J11	OPA598 VOUT, BNC female connector
J12	OPA598 VOUT and GND terminal block (screw type)

Table 2-3 lists the test points. See Figure 4-1 and Figure 4-3 for test-point locations.

Table 2-3. Test Points

Test Point	Function
TP1	Connected to VIN- input jack
TP2	GND point for VIN- TP1
TP3	OPA598 -In input pin
TP4	Connected to VIN+ input jack
TP5	GND point for VIN+ TP4
TP6	OPA598 +In input pin
TP7	GND point near TP9
TP8	OPA598 Thermal Flag pin
TP9	OPA598 Current Flag pin
TP10	OPA598 OUT pin
TP11	GND point near TP10
TP12	Test point in middle of Rx1, Rx2 feedback network circuit
TP13	GND point near TP12
TP14	Connected to VOUT jack
TP15	GND point near TP14
TP16	GND point near TP8
TP17	VDD supply voltage connects to OPA598 V+ pin
TP18	GND point common to VDD and VSS test points
TP19	VSS supply voltage connects to OPA598 V- pin

Table 2-4 lists the LED indicators, colors, and indications.

Table 2-4. LED Indicators

Indicator	LED Color	Indication
D5	GREEN	VDD is applied to the OPA598EVM.
D6	YELLOW	OPA598 has been placed in output shutdown mode.
D7	ORANGE	The OPA598 output is in current limit.
D8	RED	The OPA598 is in thermal shutdown.

2.2 Inputs

Inputs to the EVM can be a voltage level or signal that is within the OPA598 specified input voltage range, relative to the gain setting and supply voltages applied to the EVM. BNC connectors are used at the J5 (VIN–) and J9 (VIN+) inputs for signal generators or a dc source. The inputs at J5 and J9 can be monitored at TP1 and TP4, respectively. Those two test points, along with the TP2 and TP5 grounds, can be used as alternate inputs if the BNC jacks cannot be used. Some sort of clip arrangement would be required to clip onto the test points.

CAUTION

The onboard 49.9-Ω termination resistor for use with the noninverting amplifier configuration was mentioned previously. Be mindful that excessive heating of the 2-W resistor could occur under some high-input-voltage conditions, and might lead to eventual destruction of the resistor if the power dissipation is excessive.

To determine if the 49.9-Ω, 2-W R9 input resistor has a sufficient power rating for the intended RMS input voltage, apply the formula: Power = Voltage(RMS)^2 / Resistance. Alternatively, an external higher-wattage BNC terminator can be connected at one of the EVM input connectors if there is a risk of damaging R9.

Furthermore, the EVM can be set to a –1 V/V inverting gain by employing the onboard 1-kΩ, 2-W resistors: R1 input resistor and RF2 feedback resistor. If the input voltage applied to VIN– is set to either 40 V or –40 V (±42.5 V supplies), these resistors will have to dissipate as much as 1.6 W each. The EVM uses these 2-W surface-mount resistors (wide 2512) to handle this higher power-dissipation case. Similarly, these two resistors have similar power dissipation when the EVM is set up for a noninverting gain of 2 V/V.

2.3 Outputs

The OPA598 VOUT output can be monitored at the J11 BNC jack, J12 terminal block jack, or TP14 test point. A convenient ground point, TP15, is located near TP14. The EVM includes a 1-kΩ, 2-W, surface-mount, wire-wound resistor (RL) that is connected into the circuit by JP21. PCB footprints for a load capacitor (CL) and an RC snubber network (Rz, Cz) are included, but are not populated for most uses. These unpopulated components may be populated using user-supplied components.

If the load power exceeds 2 W, make sure the load is not directly attached to the OPA598EVM PC board. Instead, connect the load to the VOUT J12 terminal block using wires.

Very-fast rectifier diodes D3 and D4 are included from the OPA598 output pin to each supply rail. The diodes protect the OPA598 output stage from potential back EMF damage sometimes created by an inductive load at VOUT.

2.4 Enable or Disable

The OPA598 features output enable-disable capability. The OPA598 is enabled or *operates* by floating the E/D pin, which is the normal mode for the OPA598EVM. However, shorting the E/D pin to the E/D Com pin (labeled EDcom on the EVM board) disables the device output. JP11 on the EVM is used to control the enable-disable function. The OPA598 output is automatically enabled when JP11 is left open. However, adding a shorting jumper shunt across JP11 disables the OPA598 output. When the OPA598 is disabled, the op amp power consumption is reduced significantly.

JP11 can be driven externally from a digital source producing 3-V logic levels. An EVM input jack for that purpose is not provided, but JP11 can be used to access the enable-disable control circuitry input, if needed. The enable-disable opto-isolator circuit portion is not optimized for speed, but rather versatility; therefore, keep the switching seeds low.

A jumper shunt across JP17 sets the voltage on the E/D Com pin (EDcom), to which the E/D pin is referenced. The 3-pin, 2-positiion jumper block is located near the OPA598, and is used to connect the E/D Com pin (EDcom) to either negative supply VSS, or GND (0 V). Setting E/D Com (EDcom) to one or the other is of no consequence for the OPA598EVM because the enable-disable function behaves very much the same with either reference level. However, having the choice built into the EVM allows the OPA598 to be set to one or the other of the two most-common reference levels used for OPA598 applications.

2.5 Status Flags

The OPA598 DNT (12-pin WSON) package provides separate current limit and thermal shutdown flag functions that indicate when an overcurrent or overtemperature condition occurs. These two functions have pins that are open-drain, active-low outputs, internally referenced to the applied E/D Com pin voltage; E/D Com is shown as EDcom on the EVM board. An LED and series 820-Ω resistor serve as the pulldown load for each status flag pin to the E/D Com pin (EDcom). The OPA598EVM has a separate 3.3-V regulator that is referenced to E/D Com pin (E/D com) and serves as the supply in this circuit.

An LED illuminates when an overcurrent or overtemperature condition is reached. An orange overcurrent LED illuminates when the output current exceeds the limit selected by the jumper shunt connected across one of the JP12 through JP16, 50-mA to 250-mA current-limit selections. The red overtemperature LED activates if the OPA598 junction temperature (T_J) is greater than 150°C, but turns off after the device cools to 130°C. The OPA598EVM has an extensive heat-sinking area; therefore, triggering the overtemperature LED may be difficult. The status flag pins can be monitored externally using the TP9 current-limit test point and TP8 thermal-limit test point.

2.5.1 Circuit Protection

The OPA598 op amp and other OPA598EVM components are protected from accidental supply reversal by the inclusion of series-connected Schottky diodes directly after the power supply jacks. These diodes exhibit a small forward-voltage drop; therefore, when setting the OPA598EVM external supply voltages, the levels must be increased slightly to accommodate the diode voltage drops. The supply voltages can be monitored at the VDD (TP17) and VSS (TP19) test points that are placed after the Schottky protection diodes. TP18 is the common for these two test points.

High-current op amps such as the OPA598 are used to drive a load that presents a complex load impedance ($\mathbf{Z_L} = R \pm jX$) at the output. If this complex impedance has significant inductive reactance, the inductance can produce a back electromotive force (EMF) voltage that could potentially damage the OPA598 output stage. The OPA598EVM has ultra-fast rectifier diodes D3 and D4 connected from the output pin to the PCB internal VDD and VSS supply lines that help provide back EMF protection. The diodes act as voltage clamps helping protect the output transistors from potential high-voltage occurrences that might occur during a back EMF event.

3 Application Circuits

The OPA598EVM can be connected in a variety of standard op-amp circuits: inverting amplifier, noninverting amplifier, difference amplifier, and as an improved Howland current pump (V-I converter), as well as others. See the OPA598 data sheet for some typical application circuits.

As received, the OPA598EVM has eight (8), 100-mil jumper shunts across jumper blocks on the PCB. The locations have been selected to establish the OPA598 as either an inverting amplifier having a gain of –1 V/V when VIN– (J5) is driven, or as a noninverting amplifier having a gain of +1 V/V when VIN+ (J9) is driven.

Section 4.1.1, EVM Default Configuration, provides a simplified OPA598EVM schematic. The schematic shows the jumper shunts (SH-J#) installed at particular jumper blocks. These jumper shunts as placed set up the two described gain settings.

Some of the jumper shunts are in passive jumper block locations where they do not contribute to the functionality of the circuit. This placement was done so that all eight shunts could be provided with the EVM and would be available for use in more involved circuits.

3.1 Setting Dual-Supply or Single-Supply Operation

A decision about which OPA598 operating supply voltage or voltages are used must be decided upon before any circuit is set up on the OPA598EVM. The OPA598EVM can be used with a dual power supply from ±5 V to ±37.5 V, or a single power supply of 10 V to 85 V. The circuits built into the EVM are automatically and correctly powered for either supply arrangement.

3.1.1 Dual-Supply Operation Configuration

- External supply V+ connects to J6, labeled V+ on EVM
- External GND or Common connects to J7, labeled GND on EVM
- External supply V– connects to J8, labeled V– on EVM
- Shunt jumper JP17 jumpers pin 2 (E/D Com) to pin 3 (VSS), or pin 2 (E/D Com) to pin 1 (GND)

3.1.2 Single-Supply Operation Configuration

- External supply V+ connects to J6, labeled V+ on EVM
- External GND or Common connects to J7, labeled GND on EVM
- EVM jumper JP17 jumpers pin 2 (E/D Com) to pin 3 (VSS), or pin 2 (E/D Com) to pin 1 (GND)

3.2 Common Op-Amp Configurations

The following common circuit configurations are easily accomplished using the OPA598EVM.

3.2.1 Inverting Gain of –10 V/V

Connect the jumper shunts as listed in Table 3-1 to establish an inverting gain of –10 V/V. The jumper shunt installations are illustrated in Figure 3-1. The jumper shunts are designated in the BOM as a *shunt* and have an SH-J# part designator. The jumper shunts appear in the schematic as the red jumpers connected across the various JP# jumper blocks.

Table 3-1. Jumper Shunt Connections for an Inverting Gain of –10 V/V

Jumper Block	Jumper Shunt Connects	Notes
JP3	R1 (1 kΩ) from VIN– to OPA598 -IN pin	G = –10 V/V used
JP8	OPA598 noninverting input to GND	
JP11	Open	Enabled mode
JP13	Sets current limit to 100 mA	
JP17	E/D Com pin	E/D Com pin selection GND
JP18	RF1 (10 kΩ) inserted in OPA598 feedback path	
JP21	1-kΩ, 2-W load resistor to OPA598 output	

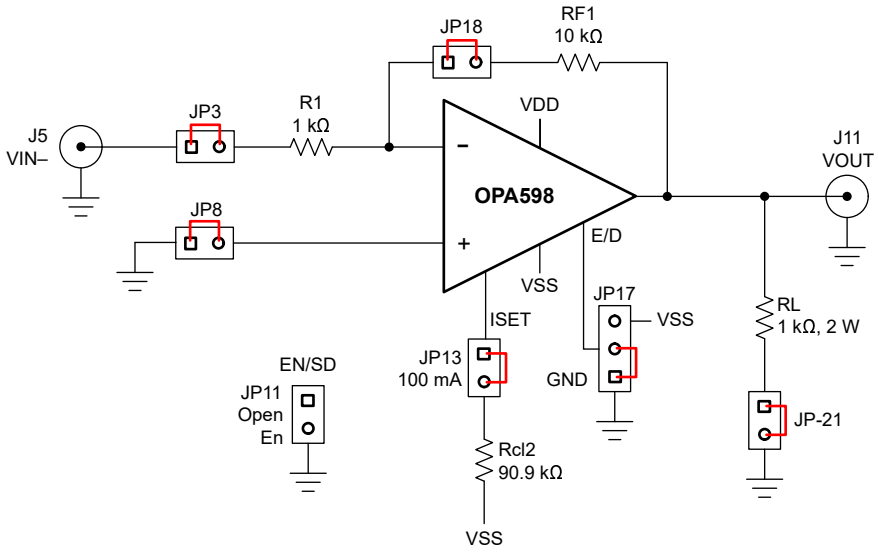


Figure 3-1. OPA598EVM Jumper Shunt Locations for G = –10 V/V Inverting Amplifier

3.2.1.1 External Connections for –10 V/V Inverting Gain Configuration

Connect the intended voltage or signal source to the OPA598EVM VIN– J5 jack using a 50-Ω coaxial cable with standard male BNC connectors. Use a similar cable to connect the OPA598EVM VOUT BNC jack, or an oscilloscope probe connected to the output oscilloscope. Connect and apply the required supply voltages to the V+, V–, and GND jacks. Turn on the input voltage or signal source (or sources) and verify the circuit functions as expected.

3.2.1.2 Inverting Gain of –10 V/V Configuration Electrical Performance

The VOUT voltage is 10x the voltage or signal applied at VIN–, J5, but have the opposite sign. In other words, if 2 VDC is applied at VIN–, the output at VOUT is –20 VDC. For an ac input signal of 2 V_{PP}, VOUT is 20 V_{PP}, and phase shifted by 180°.

The general expression for the output-to-input voltage relationship for the op amp inverting-amplifier configuration is:

$$VOUT = (VIN–)\left(\frac{-RF1}{R1}\right) \quad (1)$$

3.2.2 Noninverting Gain of +11 V/V

Connect the jumper shunts as listed in Table 3-2 to establish an inverting gain of +11 V/V. The jumper shunt installation is illustrated in Figure 3-2. The jumper shunts are designated in the BOM as a *shunt* and have an SH-J# part designator. The jumper shunts appear in the schematic as the red jumpers connected across the various JP# jumper blocks.

Table 3-2. Jumper Shunt Connections for a Noninverting Gain of +11 V/V

Jumper Block	Jumper Shunt Connects	Notes
JP2	Ri1 (10 kΩ) OPA598 –IN pin to GND	
JP5	VIN+ J9 to OPA598 noninverting input	
JP9	R8 (10 kΩ) from OPA598 noninverting input to GND	
JP11	Open	Enabled mode
JP13	Sets current limit to 100 mA	
JP17	E/D Com pin	E/D Com pin selection GND
JP18	RF1 (10 kΩ) inserted in OPA598 feedback path	
JP21	1-kΩ, 2-W load resistor to OPA598 output	

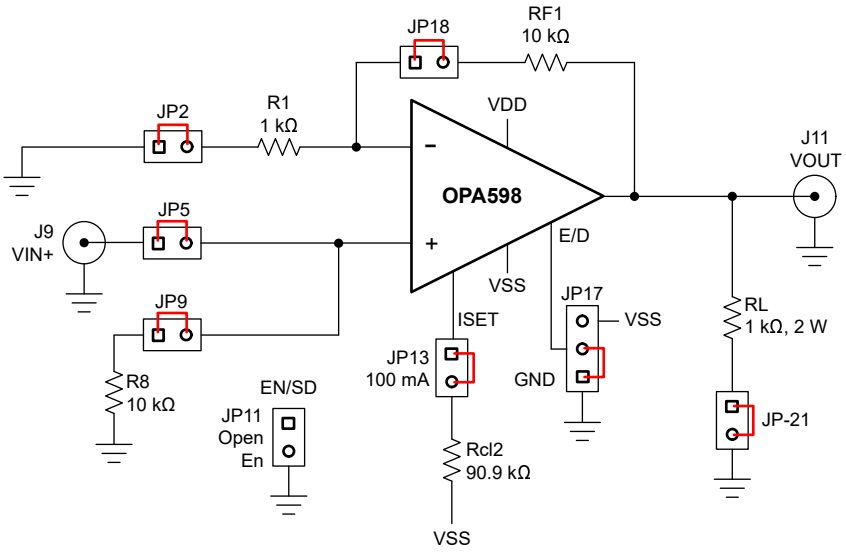


Figure 3-2. OPA598EVM Jumper Shunt Locations for G = +11 V/V Noninverting Amplifier

3.2.2.1 External Connections for Noninverting Gain Configuration

Connect the intended voltage or signal source to the OPA598EVM VIN+ J9 jack using a 50-Ω coaxial cable with standard male BNC connectors. Use a similar cable to connect the OPA598EVM VOUT BNC jack, or an oscilloscope probe connected to the output oscilloscope. Connect and apply the required supply voltages to the V+, V–, and GND jacks. Turn on the input voltage or signal source (or sources) and verify the circuit functions as expected.

3.2.2.2 Noninverting Gain Configuration Electrical Performance

The VOUT voltage is 2x the voltage or signal applied at VIN+ J9, and have the same sign. In other words, if 1 VDC is applied at VIN+, the output at VOUT is 11VDc. For an ac input signal of 1 V_{PP}, VOUT is be 11V_{PP} and in phase with the input.

The general expression for the output to input voltage relationship for the op amp noninverting-amplifier configuration is:

$$VOUT = (VIN+)\left(1 + \frac{RF1}{Ri1}\right) \quad (2)$$

3.2.3 Gain of +10 V/V Difference Amplifier

Connect jumper shunts across the jumper blocks listed in Table 3-3 to establish a difference amplifier having a gain of +10 V/V. The jumper shunt installations are illustrated in Figure 3-3. The jumper shunts are designated in the BOM as a *shunt* and have an SH-J# part designator. The jumper shunts appear n the schematic as the red jumpers connected across the various JP# jumper blocks.

Table 3-3. Jumper Shunt Connections for a Gain of +10 V/V Difference Amplifier

Jumper Block	Jumper Shunt Connects	Notes
JP3	R1 (1 kΩ) OPA598 –IN pin to VIN– J5	
JP7	VIN+ J9 to OPA598 noninverting input through R5 (1 kΩ)	R divider resistor
JP9	R8 (10 kΩ) from OPA598 noninverting input to GND	R divider resistor
JP11	Open	Enabled mode
JP13	Sets current limit to 100 mA	
JP17	E/D Com pin	E/D Com pin selection GND
JP18	RF1 (10 kΩ) inserted in OPA598 feedback path	
JP21	1-kΩ, 2-W load resistor to OPA598 output	

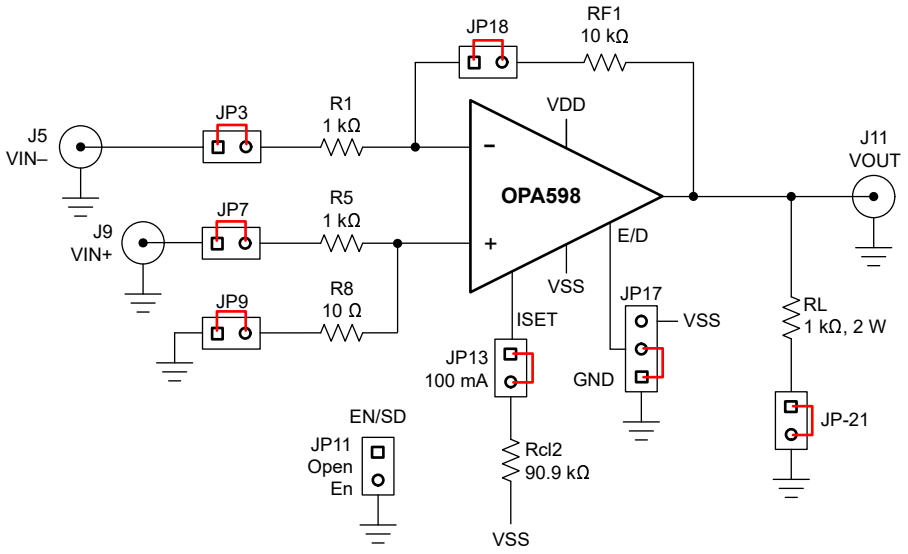


Figure 3-3. OPA598EVM Jumper Shunt Locations for G = +10 V/V Difference Amplifier

3.2.3.1 Jumper Shunt Locations for Difference-Amplifier Configuration

Connect the intended voltages or signal sources to the OPA598EVM VIN+ and VIN– jacks using a 50-Ω coaxial cable with standard male BNC connectors for each jack. Use a similar cable to connect the OPA598EVM VOUT BNC jack, or an oscilloscope probe connected to the output oscilloscope. Connect and apply the required supply voltages to the V+, V–, and GND jacks. Turn on the input voltage or signal source (or sources) and verify the circuit functions as expected.

3.2.3.2 Gain of 10 V/V Difference Amplifier Configuration Electrical Performance

The VOUT voltage is 10x the voltage difference or signals applied at VIN+ J9 and VIN– J5. If 1 VDC is applied at the VIN+ input, and –1 V is applied to the VIN– input, the input voltage difference is 2 V, and VOUT is 20 VDC. For ac input signals applied to VIN+ and VIN–, VOUT is 10x the difference between the two input signals occurring at any particular instance.

The general expression for the output-to-input voltage relationship for the op amp difference-amplifier configuration is:

$$VOUT = (VIN–)\left(\frac{-RF1}{R1}\right) + (VIN+)\left[\left(1 + \frac{RF1}{R1}\right)\left(\frac{R8}{R5 + R8}\right)\right] \quad (3)$$

3.2.4 Improved Howland Current Pump

The OPA598EVM can be configured as an improved Howland current pump that provides a transconductance amplifier function, sometimes called a V-to-I converter. Configuring the V-to-I converter with the EVM requires that one resistor, Riso2 (a wide 2512 size), be changed on the EVM PCB from 0 Ω to 49.9 Ω (2 W). If a different output current range is required, this resistor may need to be a different value. Section 3.2.3.1 shows the Riso2 relationship to the output current.

Additionally, Rhcp1 (a 0805-size, 10-kΩ resistor) must be installed at that location on the PCB. Rhcp1 resides just above C12, and up and to the right of the current-limit set resistor shorting blocks JP12 through JP16.

Connect jumper shunts as listed in Table 3-4 to configure the OPA598 as an improved Howland current pump. The jumper shunt installations are illustrated in Figure 3-4. The jumper shunts are designated in the BOM as a *shunt* and have an SH-J# part designator. The jumper shunts appear in the schematic as the red jumpers connected across the various JP# jumper blocks.

Table 3-4. Jumper Shunt Connections for an Improved Howland Current Pump

Jumper Number	Jumper Shunt Connects	Notes
JP1	VIN– J5 to OPA598 –IN pin, through Ri1 (10 kΩ)	

Table 3-4. Jumper Shunt Connections for an Improved Howland Current Pump (continued)

Jumper Number	Jumper Shunt Connects	Notes
JP6	VIN+ J9 to OPA598 noninverting input through R4 (10 kΩ)	
JP9	R8 (10 kΩ) from OPA598 noninverting input to GND	
JP11	Open	Enabled mode
JP13	Sets current limit to 100 mA	
JP17	E/D Com pin	E/D Com pin selection GND
JP18	RF1 (10 kΩ) inserted in OPA598 feedback path	
JP21	Open	IOUT flows through external load

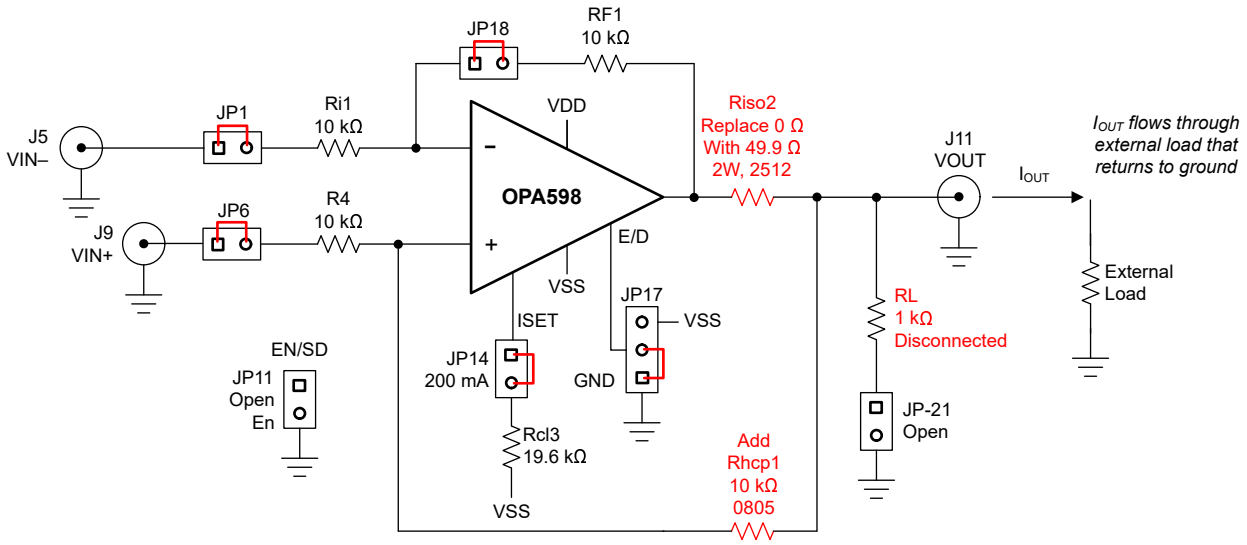


Figure 3-4. OPA598EVM Jumper Shunt Locations for an Improved Howland Current Pump

3.2.4.1 OPA598EVM Jumper Shunt Locations for an Improved Howland Current Pump

Connect the intended voltages or signal sources to the OPA598EVM VIN+ and VIN– jacks using a 50-Ω coaxial cable with standard male BNC connectors for each jack. In most cases, the easiest connection method for the Improved Howland current pump is to connect the output load to the J12 VOUT terminal block and the respective GND. To monitor the current (±) being provided by the OPA598 output, connect an ammeter in series with the load. Connect and apply the required supply voltages to the V+, V–, and GND jacks. Turn on the input voltage or signal source (or sources) and verify the circuit functions as expected.

The IOUT current is a function of the difference in voltages or signals applied to VIN+ J9 and VIN– J5. For the specific condition set up on the OPA598EVM where Ri1 = RF1 = R4 = Rhcp1 = 10 kΩ, the transfer function is simply:

$$IOUT = \frac{[(VIN+) - (VIN-)]}{Riso2} \quad (4)$$

Riso2 = 49.9 Ω is a constant that scales the IOUT output current. The scaling is different when Riso is set to a different value. Select the value of Riso2 so that the current range coincides with the OPA598 data sheet specifications.

Practically, the OPA598 improved Howland current pump circuit can provide the IOUT current through a very-low load resistance of a few Ohms. The high-end voltage is limited by the op amp output voltage compliance range, which is in proportion to the supply voltages being used.

4 Hardware Design Files

This section provides the OPA598EVM hardware schematics, PCB layout and Bill of Materials.

4.1 EVM Schematic

Figure 4-1 shows the complete OPA598EVM schematic.

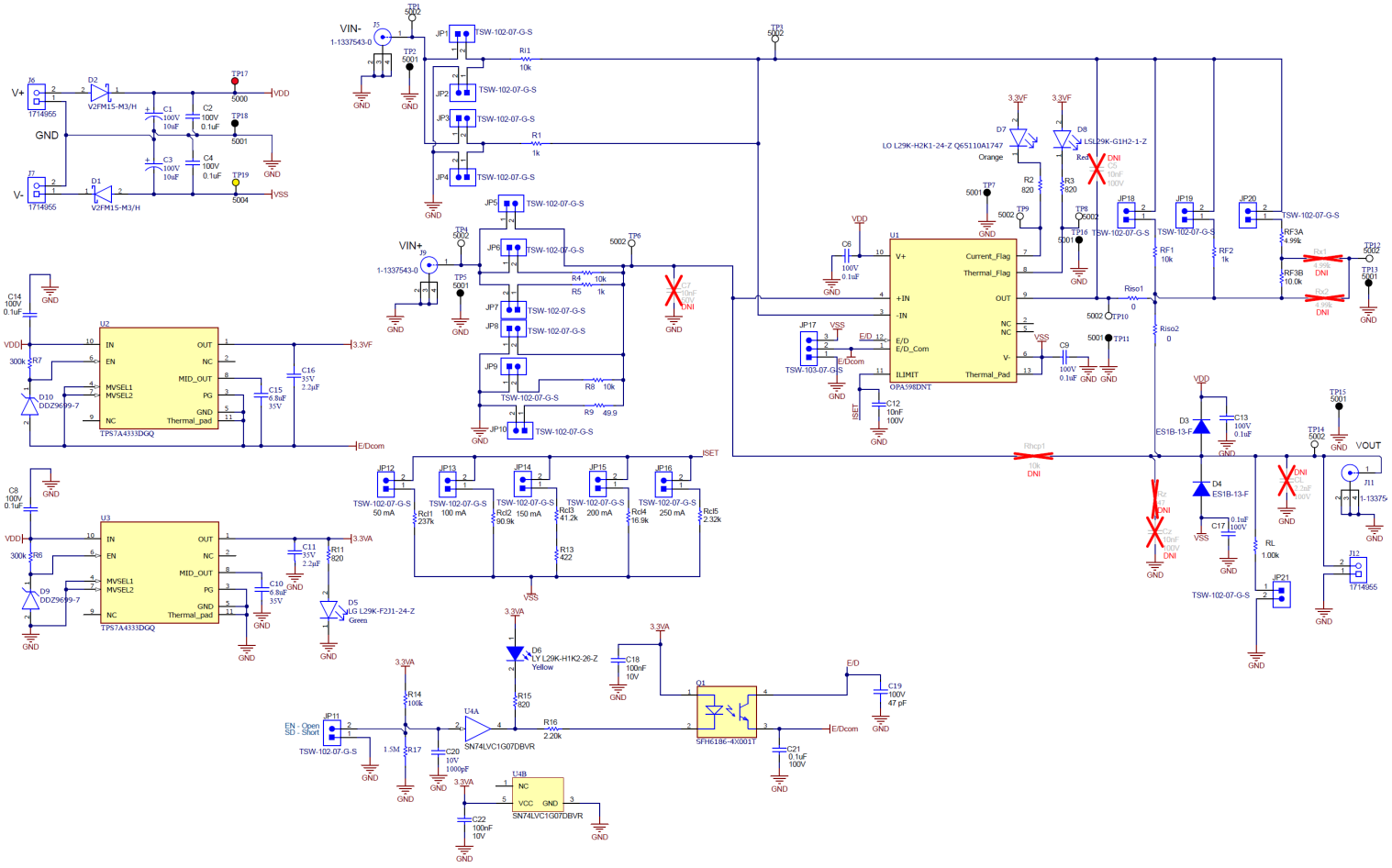


Figure 4-1. OPA598EVM Complete Schematic

4.1.1 EVM Default Configuration

The OPA598EVM ships in a configuration that allows the EVM to be directly applied as an inverting or noninverting amplifier. The jumper shunts as positioned establish the OPA598 as either an inverting amplifier having a gain of –1 V/V when J5 is driven, or a noninverting amplifier having a gain of +2 V/V when J9 is driven. J9 has a 49.9-Ω, 2-W input terminator connected by a jumper shunt into the input circuit. An external 50-Ω terminator can be placed at the J5 BNC connector when 50-Ω termination is required.

Figure 4-2 shows the default configuration schematic. The complete OPA598 EVM schematic is extensive; therefore, this simplified default schematic is provided to help make the amplifier configuration apparent. See Figure 4-1 for the entire OPA598EVM circuitry and how the Figure 4-2 circuit fits within.

The jumper shunt installations illustrated in Figure 4-2 are designated in the bill of material as a *shunt,* with an SH-J# part designator. The jumper shunts in Figure 4-2 appear as the red jumpers connected across the various JP# jumper blocks. Arbitrary SH-J# shunt numbers are assigned for this circuit only.

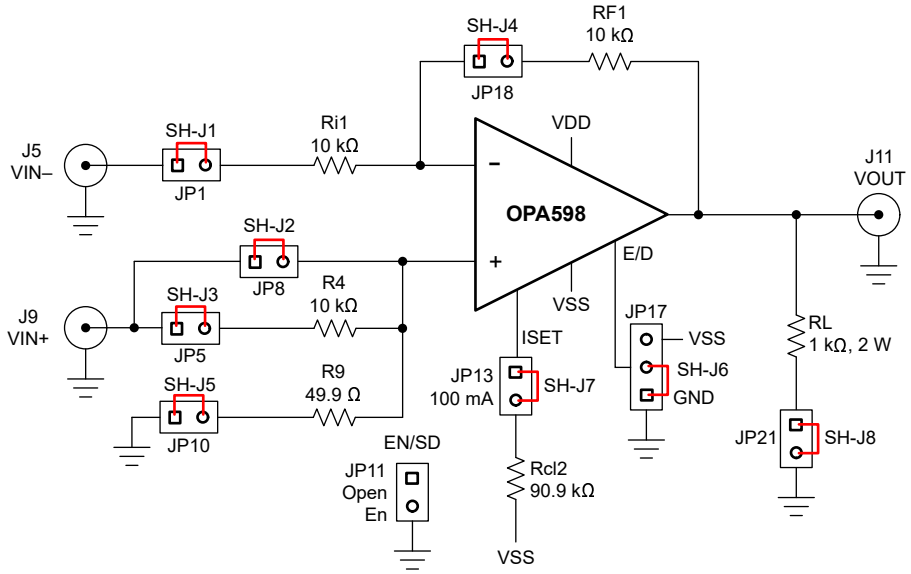


Figure 4-2. Simplified Schematic of OPA598EVM Amplifier Default Configuration

4.2 PCB Layout

Figure 4-3 and Figure 4-4 show the OPA598EVM PCB top-side and bottom-side views of the PCB layout, respectively.

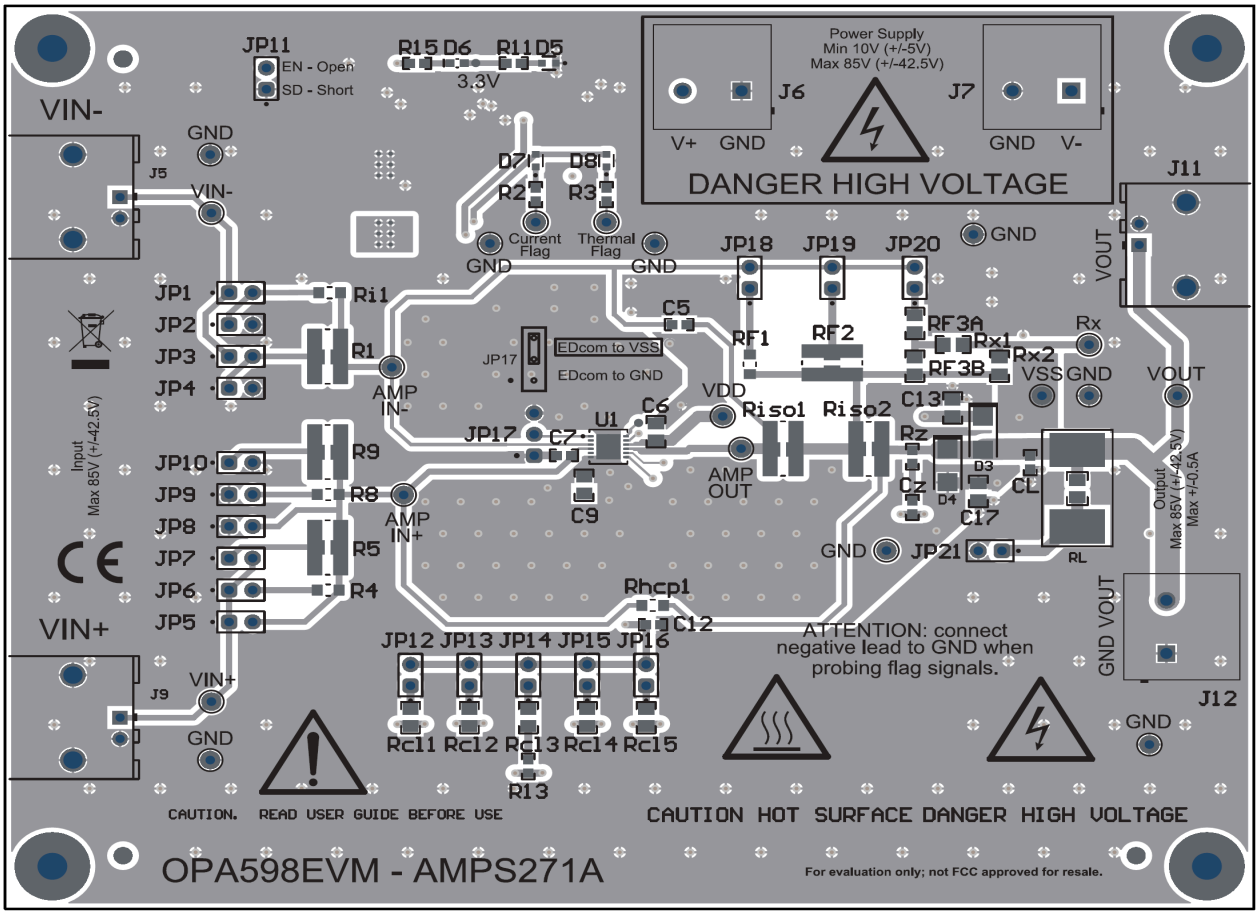


Figure 4-3. Top-Side View of the OPA598EVM PCB

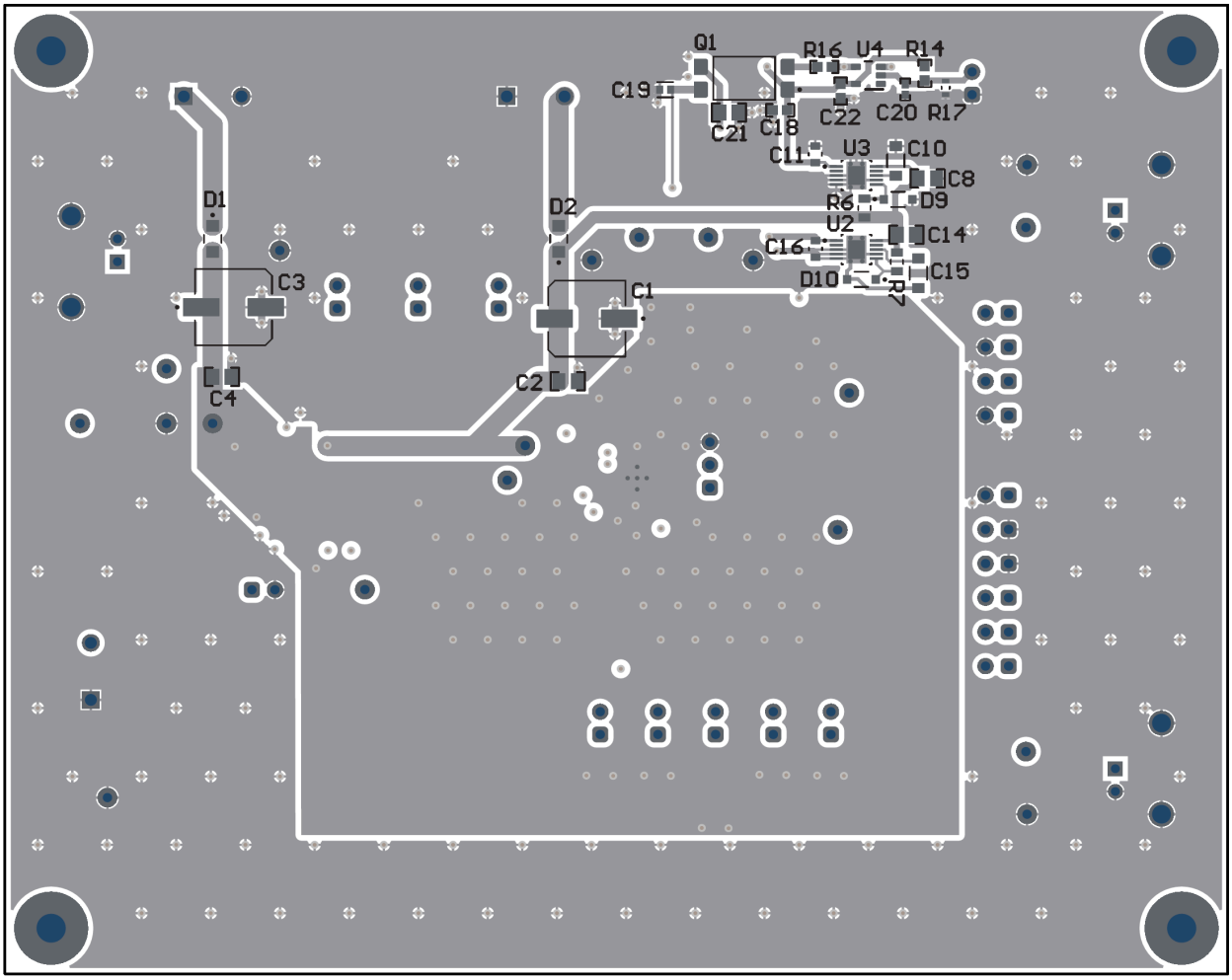


Figure 4-4. Bottom-Side View of the OPA598EVM PCB

4.3 Bill of Materials

Table 4-1 lists the bill of materials (BOM) used for the OPA598EVM.

Table 4-1. OPA598EVM Bill of Materials

Designator	Quantity	Value	Part Number	Manufacturer	Fitted
C1, C3	2	10µF	EEEHD2A100P	Panasonic	Fitted
C2, C4, C6, C8, C9, C13, C14, C17, C21	9	0.1uF	C2012X5R2A104K125AA	TDK	Fitted
C10, C15	2	6.8µF	CGA5L1X7R1V685M160AC	TDK	Fitted
C11, C16	2	2.2µF	CGA4J1X7R1V225M125AE	TDK Corporation	Fitted
C12	1	0.01uF	C0603C103J1RACTU	Kemet	Fitted
C18, C22	2	0.1uF	0603ZC104KAT2A	AVX	Fitted
C19	1	47pF	C0603C470K1GACTU	KEMET	Fitted
C20	1	1000pF	GRM155R61A102KA01D	MuRata	Fitted
D1, D2	2		V2FM15-M3/H	Vishay	Fitted
D3, D4	2	100V	ES1B-13-F	Diodes Inc.	Fitted
D5	1			Osram	Fitted
D6	1	Yellow	LY L29K-H1K2-26-Z	OSRAM	Fitted
D7	1		LO L29K-H2K1-24-Z Q65110A1747	OSRAM Opto Semiconductors	Fitted
D8	1		LSL29K-G1H2-1-Z	OSRAM Opto Semiconductors	Fitted
D9, D10	2		DDZ9699-7	Diodes Inc.	Fitted
H1, H2, H3, H4	4		NY PMS 440 0025 PH	B&F Fastener Supply	Fitted
H5, H6, H7, H8	4		1902C	Keystone	Fitted
J5, J9, J11	3		1-1337543-0	TE Connectivity	Fitted
J6, J7, J8, J12, J13	5		108-0740-001	Cinch Connectivity	Fitted
JP1, JP2, JP3, JP4, JP5, JP6, JP7, JP8, JP9, JP10, JP11, JP12, JP13, JP14, JP15, JP16, JP18, JP19, JP20, JP21	20		TSW-102-07-G-S	Samtec	Fitted
JP17	1		TSW-103-07-G-S	Samtec	Fitted
Q1	1	55V	SFH6186-4X001T	Vishay	Fitted
R1, R5, RF2	3	1k	RCL12251K00FKEG	Vishay Dale	Fitted
R2, R3, R11, R15	4	820	RC0603FR-07820RL	Yageo	Fitted
R4, R8, RF1, Ri1	4	10k	CMP0805AFX-1002ELF	Bourns	Fitted
R6, R7	2	300k	RMCF0805FT300K	Stackpole	Fitted
R9	1	49.9	RCL122549R9FKEG	Vishay Dale	Fitted
R13	1	422	RC0603FR-07422RL	Yageo	Fitted
R14	1	100k	CRCW0603100KFKEA	Vishay-Dale	Fitted
R16	1	2.20k	RC0603FR-072K2L	Yageo	Fitted

Table 4-1. OPA598EVM Bill of Materials (continued)

Designator	Quantity	Value	Part Number	Manufacturer	Fitted
R17	1	1.5M	KTR03EZPF1504	Rohm	Fitted
Rcl1	1	237k	CRCW0805237KFKEA	Vishay-Dale	Fitted
Rcl2	1	90.9k	CRCW080590K9FKEA	Vishay-Dale	Fitted
Rcl3	1	41.2k	ERJ-6ENF4122V	Panasonic	Fitted
Rcl4	1	16.9k	ERJ-6ENF1692V	Panasonic	Fitted
Rcl5	1	2.32k	CRCW08052K32FKEA	Vishay-Dale	Fitted
RF3A	1	4.99k	CRCW08054K99FKEA	Vishay-Dale	Fitted
RF3B	1	10.0k	MCU0805MD1002BP100	Vishay/Beyschlag	Fitted
Riso1, Riso2	2	0	RCA12250000Z0EGLS	Vishay Dale	Fitted
RL	1	1.00k	WSC45271K000FEA	Vishay-Dale	Fitted
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8	8	1x2	SNT-100-BK-G	Samtec	Fitted
TP1, TP3, TP4, TP6, TP8, TP9, TP10, TP12, TP14	9		5002	Keystone	Fitted
TP2, TP5, TP7, TP11, TP13, TP15, TP16, TP18	8		5001	Keystone	Fitted
TP17	1		5000	Keystone	Fitted
TP19	1		5004	Keystone	Fitted
U1	1		OPA598DNT	Texas Instruments	Fitted
U2, U3	2		TPS7A4333DGQ	Texas Instruments	Fitted
U4	1		SN74LVC1G07DBVR	Texas Instruments	Fitted
C5, Cz	0	0.01uF	C0603C103J1RACTU	Kemet	Not Fitted
C7	0	0.01uF	C1608X7R1H103K080AA	TDK	Not Fitted
CL	0	2200pF	CGA3E2X7R2A222K080AA	TDK	Not Fitted
FID1, FID2, FID3	0		N/A	N/A	Not Fitted
Rhcp1	0	10k	CMP0805AFX-1002ELF	Bourns	Not Fitted
Rx1, Rx2	0	4.99k	CRCW08054K99FKEA	Vishay-Dale	Not Fitted
Rz	0	47	CRCW060347R0JNEA	Vishay-Dale	Not Fitted

5 Reference

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CAUTION

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- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

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Last updated 10/2025