EVM User's Guide: TSG06D00EVM

6GHz Dual-Channel RF Signal Generator Evaluation Module User's Guide

Description

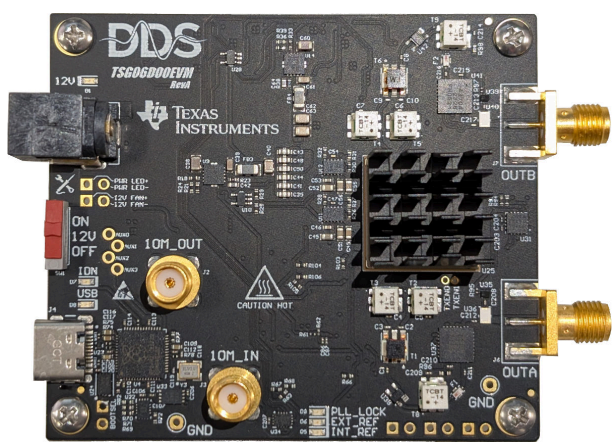
The TSG06D00EVM is a dual-channel 6GHz RF signal generator evaluation module from Texas Instruments designed for engineers who need a compact, USB-controlled RF source for lab bench use, system evaluation, and automated test applications. The device provides two semi-independent, coherent RF output channels with calibrated power output and a full SCPI command set accessible over USB-TMC.

Get Started

1. Order the TSG06D00EVM from TI.com.
2. Download the latest software from TSG06D00EVM-GUI.
3. Download the comprehensive references from the TSG06D00EVM tool page.
   a. Hardware design files (schematic, layout, bill of materials)
   b. Performance data and test report
   c. Technical reference manual (SCPI commands, debug instructions)

Features

- Two semi-independent 10MHz to 6GHz outputs
  – Less than 1nHz frequency resolution
- Onboard clocking with optional 10MHz reference
- Optimized power tree from 12V input
- Integrated RF output power detection
- USB-C control with NI-VISA driver for SCPI



TSG06D00EVM Hardware Board

1 Evaluation Module Overview

1.1 Introduction

The following user guide gives an in-depth overview on using the TSG06D00EVM evaluation board hardware as well as the software GUI, example commands and scripts to change, configure and evaluate the signal generator in the various modes and features.

1.2 Kit Contents

- TSG06D00EVM
- USB Type-C Cable®
- 12V DC power cable (5.5mm OD / 2.1mm ID, positive center)

See Section 2.2 for additional equipment required for proper usage.

1.3 Device Information

The TSG06D00EVM uses the following devices from Texas Instruments.

Table 1-1. Device Information

Device	Description
DDS39RF12	16-bit, 2-channel, 24GSPS 12GHz RF direct digital synthesizer (DDS)
LMX2820	22.6GHz wideband RF synthesizer with phase synchronization, JESD and <5µs frequency calibration
LMK04828	Ultra-low-noise JESD204B compliant clock jitter cleaner with integrated 2370MHz to 2630MHz VCO
LMH2110	8GHz logarithmic RMS power detector with 45dB dynamic range
TPS259261	4.5V to 13.8V, 30mΩ, 2 to 5A eFuse
TPSM82916	17V VIN, 6A low-noise low-ripple buck module with integrated ferrite bead filter compensation
TPSM82822	5.5V input, 2A step-down module with integrated inductor in 2 × 2.5 x 1.1mm µSIP package
LM27762	Low-noise positive- and negative-output charge pump with integrated LDO
TPS7A9601	2A, ultra-low-noise ultra-high PSRR RF voltage regulator

2 Hardware

2.1 Board Overview

2.1.1 RF Signal Chain

The TSG06D00EVM has two semi-independent RF output channels each with an identical RF signal chain capable of outputing signals from 10MHz to 6GHz with <1nHz frequency resolution.

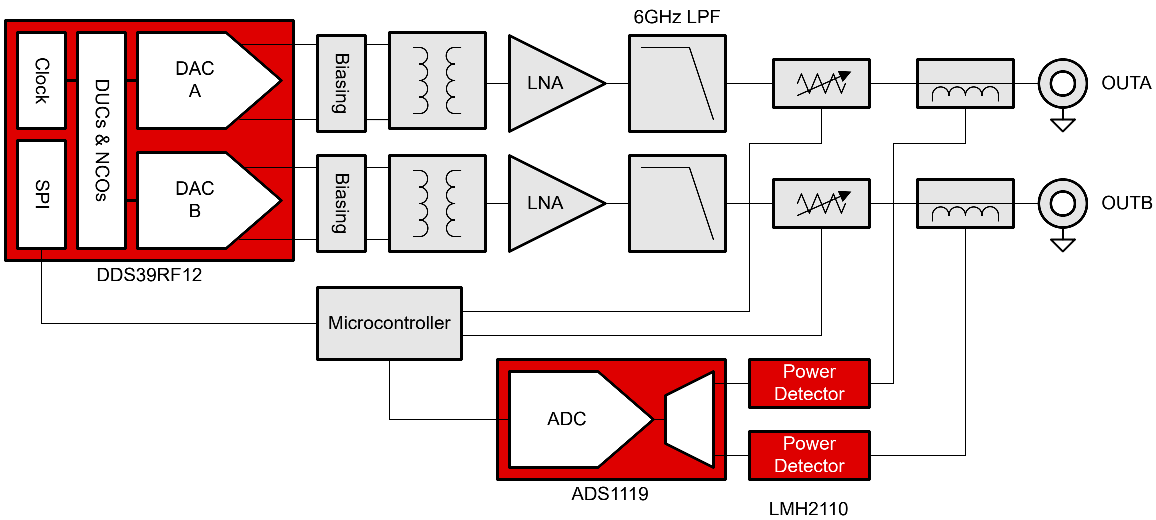


Figure 2-1. RF Output Block Diagram

The DDS39RF12 operates in two sample rate modes. Both channels share the same sample clock from the LMX2820, so the mode in use affects both channels.

Table 2-1. Frequency Ranges

Frequency Range	Both Channels Independent?	Notes
10MHz to 4.8GHz	Yes	Both channels can operate fully independently when both are in use in the same frequency range.
4.8GHz to 6GHz	Yes	
Mixed (one channel in each range)	With caveats	The instrument switches the DAC sample rate to accommodate the new channel frequency. The other channel continues to operate but due to aliasing, image frequencies can be present. The user is responsible for verifying output spectral purity in this configuration.

2.1.1.1 Output Power

The TSG06D00EVM is able to provide up to 14dBm output power at low frequency (10MHz) and up to 0dBm at high frequency (6GHz) with a roughly linear dropoff over the full frequency range.

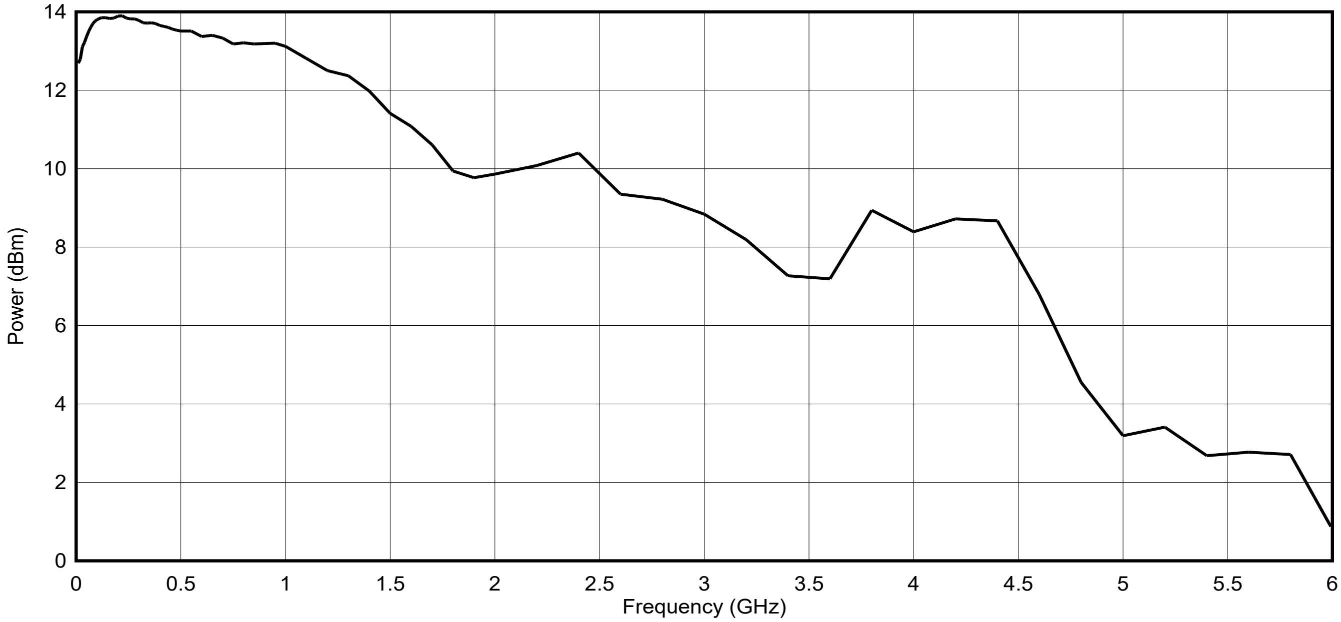


Figure 2-2. Output Power vs Output Frequency

2.1.2 Clocking

The board has on-board clocking using a 100MHz VCXO as a frequency reference to the LMK04828 jitter cleaner to condition the clock signal before being feed to the LMX2820 RF synthesizer to generate up to a 12GHz clock to the DDS39RF12 direct digital synthesizer.

An on-board 10MHz TCXO provides a low frequency clock for synchronization or an external 10MHz option is available. Both internal and external references are buffered and routed to a 10MHz output to provide a reference to another board or instrument.

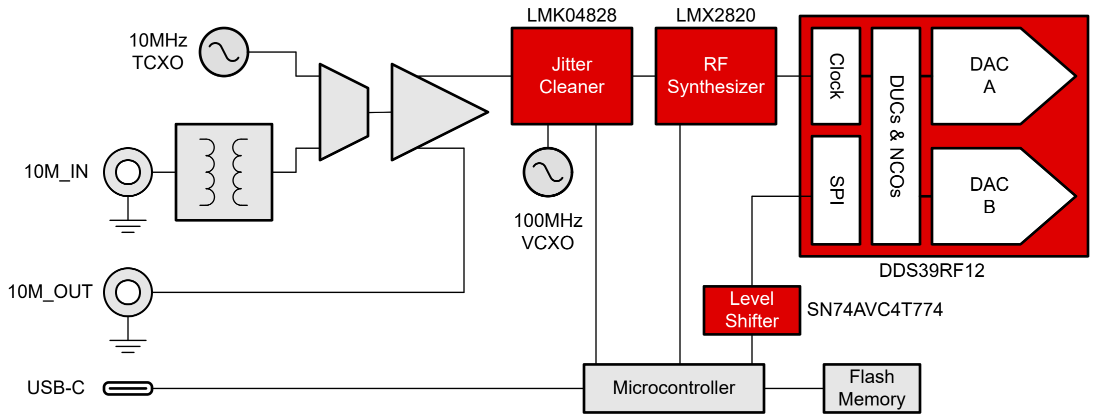


Figure 2-3. Clock Block Diagram

2.1.3 Power

The board runs off a 12V power supply and uses a selection of TI power components to provide the needed voltages to all of the components while minimizing introducing additional noise and distortion to the sensitive RF signal path.

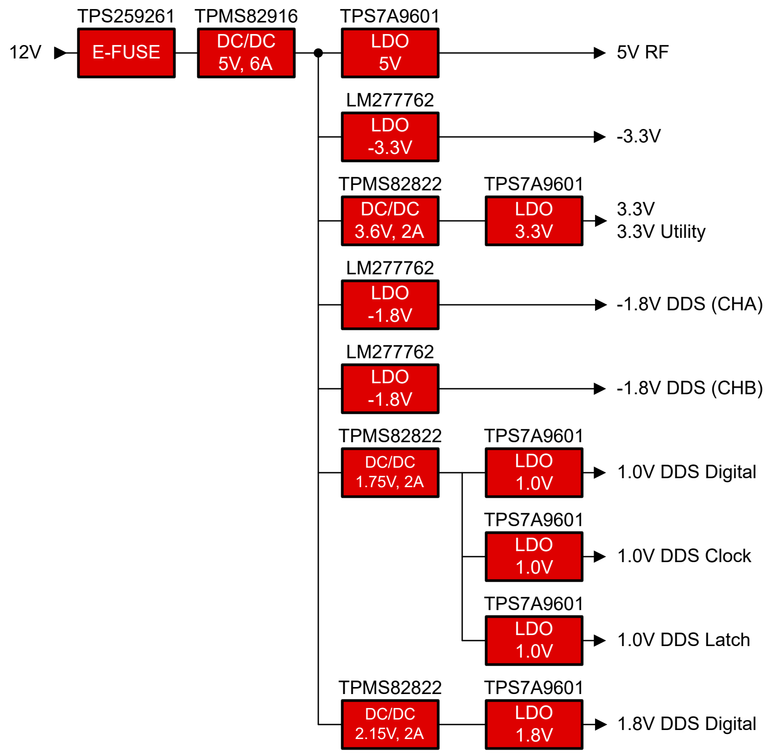


Figure 2-4. Power Block Diagram

2.2 Required Equipment

The following equipment is not included with the EVM kit but is required for proper usage.

- 12V power supply capable of supplying 1.5A. The EVM does include a DC barrel plug adapter (with 5.5mm OD / 2.1mm ID, positive center).
- Band-pass filters for the RF outputs. TI recommends using filters with a narrow pass band (within 5% to 15% of the desired bandwidth) and minimal insertion loss.
- SMA cables for the RF outputs and 10MHz reference input/output (if used for synchronization).

2.3 Hardware Setup

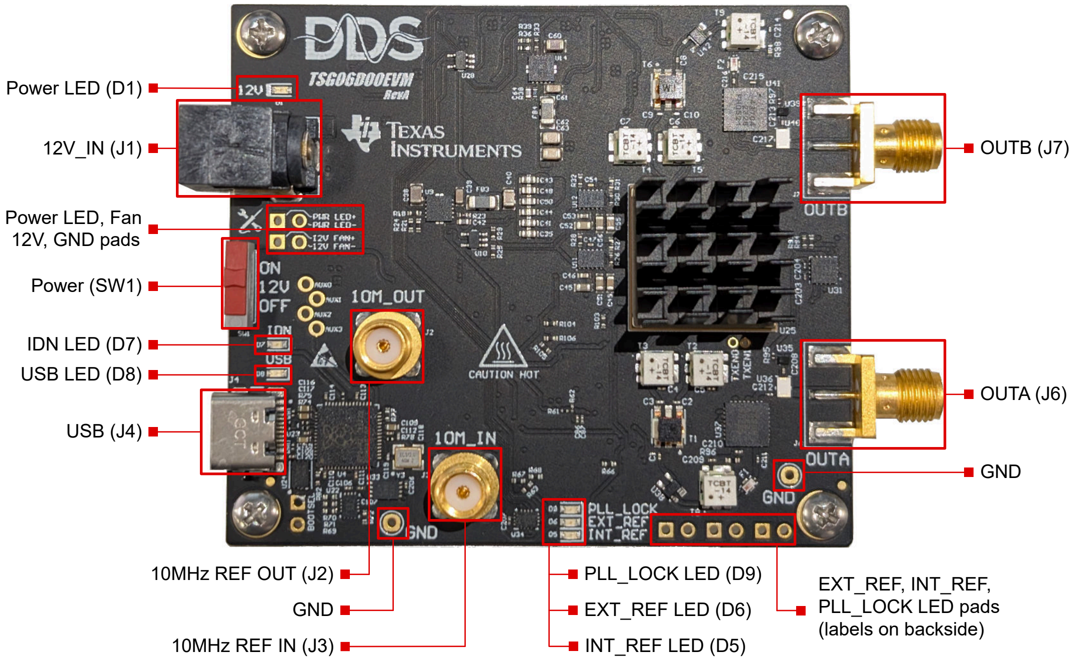


Figure 2-5. Board Connections, Indicators, and Controls

1. Connect 12V DC power (J1)
    a. Connect a 12V DC, 1.5A minimum supply to J1 (barrel jack, 5.5mm OD / 2.1mm ID, positive center).
    b. Leave SW1 in the OFF position until all cables are connected.
2. Connect RF outputs (OUT A, OUT B)
    a. Connect 50Ω SMA cables from OUTA (J6) and/or OUTB (J7) to your instruments or device-under-test (DUT).
    b. Install 50Ω SMA terminators on any port that is not used.
3. Reference clock (optional)
    a. Internal reference is selected by default; no cable needed.
    b. For external 10MHz: connect a clean source to 10M_IN (J3), then send ROSC:SOUR EXT after power-on. The on-board TCXO is powered off automatically in external mode.
4. Connect USB for SCPI (J4)
    a. Connect a USB 2.0 cable from J4 (USB-C) to your host PC.
    b. This carries SCPI commands only. The board does not draw power from USB.
5. Enable board power (SW1)
    a. Toggle SW1 to the ON position. Confirm the 12V power indicator LED illuminates.

2.4 LED Indicators

The LEDs in the following table are available to quickly check the status of the board. Additional pads are designed on the PCB to solder external LEDs for use in a mounted application or enclosure.

Table 2-2. LED Indicators

Name	Designator	Function	Description
12V	D1	12V power indicator	Illuminates when 12V power is present and SW1 is ON. If this LED is off, the board has no power.
PWR LED+ PWR LED-	Pad	Power LED (external)	Pads to solder an external LED to indicate 12V power if mounted in an enclosure.
INT_REF	D5	Internal reference lock	Indicates LMX2820 PLL lock status when the instrument is in internal reference mode. Steady = locked and operating normally.
EXT_REF	D6	External reference lock	Indicates LMX2820 PLL lock status when the instrument is in external reference mode. Steady = locked to the external 10MHz source.
IDN	D7	Identification	Illuminates when a *IDN? query is received. Useful for identifying which board on a bench is responding to USB commands.
USB	D8	USB	USB 5V power indicator
PLL_LOCK	D9	PLL lock indicator	Indicates LMX2820 PLL lock status. Steady = locked and operating normally.
PLL_LOCK LED+ PLL_LOCK LED-	Pad	PLL lock indicator (external)	Pads to solder an external LED for PLL_LOCK if mounted in an enclosure.
INT_REF LED+ INT_REF LED-	Pad	Internal reference lock (external)	Pads to solder an external LED for INT_REF if mounted in an enclosure.
EXT_REF LED+ EXT_REF LED-	Pad	External reference lock (external)	Pads to solder an external LED for EXT_REF if mounted in an enclosure.

2.5 Inputs, Outputs, and Controls

The inputs, outputs, and controls in the following table are available on the board.

Table 2-3. Inputs, Outputs, and Controls

Name	Designator	Connector	Direction	Description
12V_IN	J1	Barrel jack	Input	12V DC board power. Positive center, 1.5A minimum. Power to the board is switched by SW1 after connecting the supply.
Fan (External)	12V FAN+ 12V FAN-	Pad	Output	12V DC and GND connectors to solder an external fan if mounted in an enclosure.
USB	J4	USB 2.0 Type-C	Control	SCPI command interface only. Enumerates as USB-TMC (VID 0x2E8A, PID 0x1107). Does not supply power to the board.
10M_OUT	J2	SMA female	Output	10MHz reference output. Buffered reference signal available for daisy-chaining or external instruments.
10M_IN	J3	SMA female	Input	External 10MHz reference input.
OUTA	J6	SMA female	Output	Channel A main RF output. Terminate if unused.
OUTB	J7	SMA female	Output	Channel B main RF output. Identical signal chain to Channel A. Terminate if unused.

CAUTION

An unterminated SMA output with power enabled is bad practice at high RF power levels - it can stress the output stage and radiate unintentionally. Fit a 50Ω SMA termination on any unused output or send the OUTP 0 command on that channel.

2.6 USB Interface

The TSG06D00EVM enumerates as a USB Test and Measurement Class (USBTMC) device. Any VISA-compatible software can detect the USBTMC automatically.

The following Python example reads back the vendor ID and product ID over USB.

```
# pip install pyvisa pyvisa-py
import pyvisa
import time

rm = pyvisa.ResourceManager()
# Filter by TI USB VID 0x2E8A, PID 0x1107
matches = [r for r in rm.list_resources() if '2E8A'in r]
if not matches:
    raise RuntimeError('TSG06D00EVM not found - check 12V power and USB cable')
sg = rm.open_resource(matches[0])
sg.timeout = 5000

print(sg.query('*IDN?'))
    Texas\sInstruments,TSG06D00EVM,3XVhZkw5942P4x73,v0.9.2
```

Table 2-4. USB Parameters

Parameter	Value	Description
USB VID	0x2E8A	Vendor ID - Texas Instruments
USB PID	0x1107	Product ID - Texas Instruments USB-TMC SCPI interface
Device class	USB-TMC	USBTMC 488.2
Recommended timeout	5000ms	Calibration sweeps can take several seconds
Terminator	\n	Newline-terminated responses

3 Software

3.1 Required Software

The hardware can be controlled using the provided GUI or directly controlled through SCPI commands. Python is used as an example for scripted control. Download and install the latest GUI software through the TSG06D00EVM tool page on TI.com.

- TSG06D00EVM-GUI
- Python

3.2 GUI Installation

1. Download and install the latest GUI software.

4 Implementation Results

4.1 Evaluation Setup

1. Connect the hardware as specified in Section 2.3.
2. Start the GUI software and the software will auto detect the connected hardware.
3. Use the GUI to control the output state, frequency, phase, and amplitude of the RF outputs, as well as whether to use the on-board or an external reference.
    a. A command line interface is available to use the SCPI commands specified in the technical reference manual for advanced control of the hardware.

4.2 SCPI Control Example

Run these commands using a SPCI-compatible terminal after first power-on to verify the board is operational before going further. More commands are available in the technical reference manual.

Sending the identification command to the TSG06D00EVM to confirm successful connection.

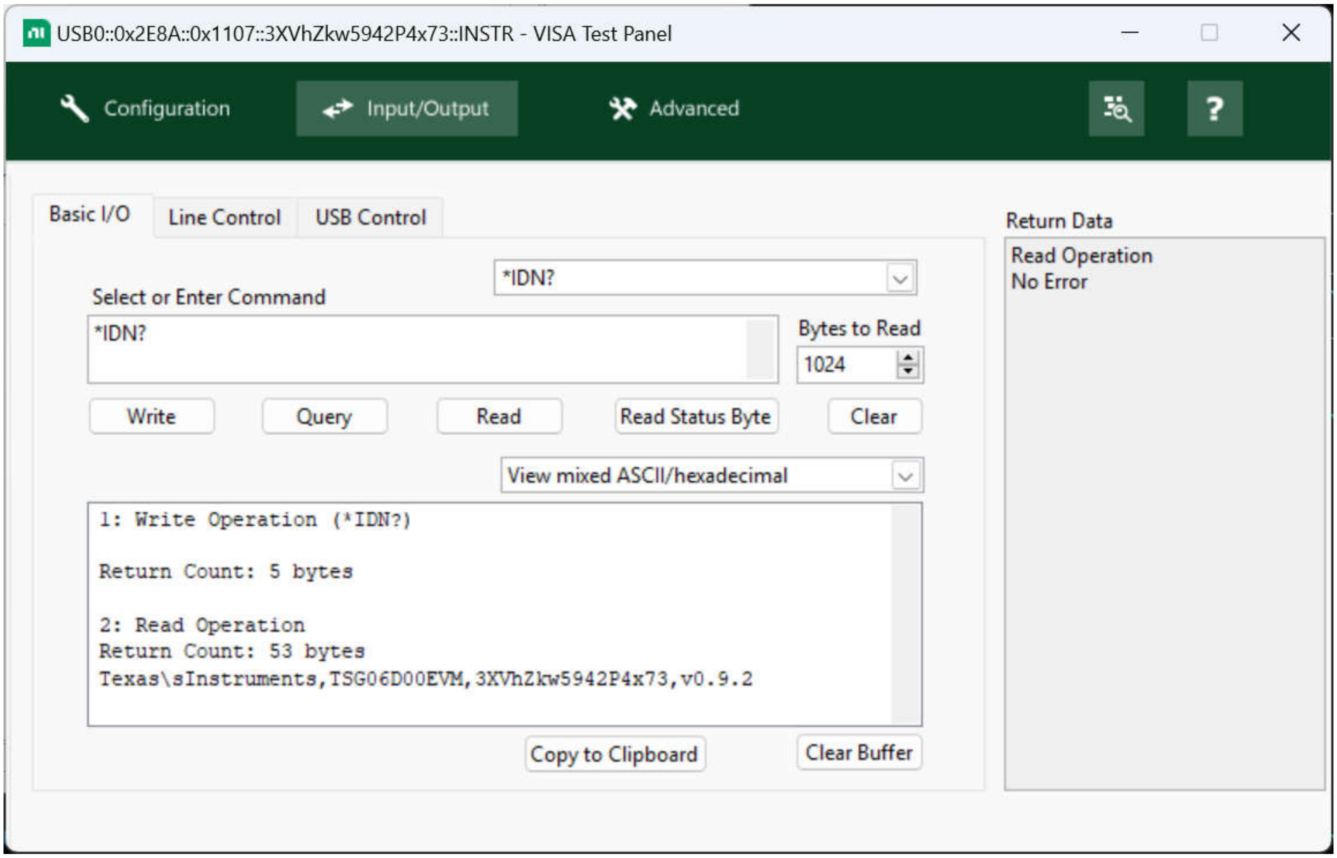


Figure 4-1. SCPI-Compatible Terminal

```
# 1. Identify the instrument
*IDN?
  Texas\sInstruments,TSG06D00EVM,3XVhZkw5942P4x73,v0.9.2
# 2. Run built-in self-test
*TST?
  PASS
# 3. Check error queue is empty
SYST:ERR:COUNT?
  0
# 4. Select Channel A and set to 1 GHz, -5dBm, 0 deg phase
INST:NSEL 1
FREQ 1e9
POW -5.0
PHAS 0.0
# 5. Enable output and measure
OUTP 1
POW?
  -5.23
# 6. Disable output when done
OUTP 0
```

Note

*TST? returns PASS and POW? returns a plausible dBm reading. If power reads as unexpected, run output calibration first.

4.3 Python Scripting Example

The following example python script can be used to directly control the board without the need for the GUI. More commands are available in the technical reference manual.

```
# pip install pyvisa pyvisa-py
import pyvisa
import time

rm = pyvisa.ResourceManager()
matches = [r for r in rm.list_resources() if '2E8A' in r]
if not matches:
    raise RuntimeError('TSG06D00EVM not found - check 12V power and USB cable')
sg = rm.open_resource(matches[0])
sg.timeout = 5000
print(sg.query('*IDN?'))
assert sg.query('*TST?').strip() == 'PASS', 'Self-test failed'
sg.write('SYST:ERR:CLEAR')

# Set 10 MHz Reference to Internal
sg.write('ROSC:SOUR INT')
print(f"Reference Mode: {sg.query('ROSC:SOUR?')}")

# Configure CH A - 1 GHz, -5 dBm, 0° Phase
sg.write('INST:NSEL 1')
sg.write('FREQ 1e9')
sg.write('POW -5')
sg.write('PHAS 0.0')
sg.write('OUTP 1')
time.sleep(0.1)

# Readback State of CH A
freq_a =float(sg.query('FREQ?'))
power_a =float(sg.query('POW?'))
phase_a =float(sg.query('PHAS?'))
output_a =float(sg.query('OUTP?'))
print(f"Channel A:")
print(f" Frequency: {freq_a/1e9:.4f} GHz")
print(f" Power: {power_a:.2f} dBm")
print(f" Phase: {phase_a} deg")
print(f" Output: {'ON'if output_a else'OFF'}")

# Configure CH B - 2.4 GHz, -10 dBm, +90° Phase
sg.write('INST:NSEL 2')
sg.write('FREQ 2.4e9')
sg.write('POW -10')
sg.write('PHAS 90.0')
sg.write('OUTP 1')
time.sleep(0.1)

# Readback State of CH B
freq_b =float(sg.query('FREQ?'))
power_b =float(sg.query('POW?'))
phase_b =float(sg.query('PHAS?'))
output_b =float(sg.query('OUTP?'))
print(f"Channel B:")
print(f" Frequency: {freq_b/1e9:.4f} GHz")
print(f" Power: {power_b:.2f} dBm")
print(f" Phase: {phase_b} deg")
print(f" Output: {'ON'if output_b else'OFF'}")

# Check for Errors
if int(sg.query('SYST:ERR:COUNT?')) >0:
    print('Error:', sg.query('SYST:ERR:NEXT?'))

# Uncomment lines below to disable both channels when done
# sg.write('INST:NSEL 1')
# sg.write('OUTP 0')
# sg.write('INST:NSEL 2')
# sg.write('OUTP 0')
# sg.close()
```

4.4 Power Combining

Both channels can be coherently combined to achieve approximately 6dB higher output power at a single frequency. This requires that both channels be in the same operating range.

1. Connect OUT A and OUT B to the two input ports of a Wilkinson combiner, hybrid coupler, or equivalent 50Ω combiner. Use matched cable lengths to both ports. Connect a spectrum analyzer or power meter to the combiner output.
2. Both channels must be tuned to the same frequency and both outputs must be enabled.
3. Set Channel A phase to 0 degrees: INST:NSEL 1 then PHAS 0. Channel A is your reference.
4. Select Channel B (INST:NSEL 2) and sweep its phase while monitoring the combiner output power. The combined power peaks when the two signals arrive at the combiner in phase. Expect approximately 6dB above a single channel. If you sweep too far, the signals begin to cancel and the power drops.

SCPI Commands

```
# Channel A - reference, phase = 0
INST:NSEL 1
FREQ 1e9
POW 5.0
PHAS 0
OUTP 1
# Channel B - sweep phase until combined power peaks
INST:NSEL 2
FREQ 1e9
POW 5.0
OUTP 1
PHAS 0    # adjust until POW? peaks
```

Use POW? on Channel A to monitor the onboard coupled detector while adjusting phase on Channel B. For best accuracy use an external power meter on the combiner output, as the onboard detector only sees one channel at a time.

5 Hardware Design Files

Hardware design files are available from the TSG06D00EVM tool page on TI.com.

5.1 Schematics

Schematics are available from the TSG06D00EVM tool page on TI.com.

5.2 PCB Layouts

PCB layout files are available from the TSG06D00EVM tool page on TI.com.

5.3 Bill of Materials (BOM)

Bill of materials is available from the TSG06D00EVM tool page on TI.com.

6 Additional Information

Trademarks

USB Type-C Cable® is a registered trademark of USB Implementers Forum.

All trademarks are the property of their respective owners.