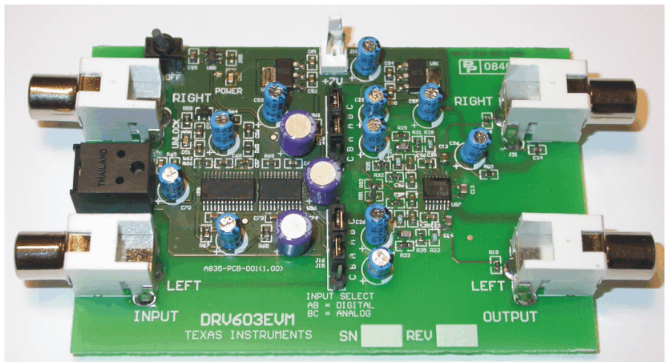
User's Guide

SLOU252A–December 2008–Revised January 2009

DRV603EVM



DRV603EVM

This user's guide describes the operation of the DRV603 evaluation module. This document also provides measurement data and design information including a schematic, bill of materials, and printed circuit board (PCB) layout drawings.

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1 Overview

The DRV603EVM customer evaluation module (EVM) demonstrates the capabilities and operation of the DRV603 integrated circuit from Texas Instruments.

The DRV603 is a 2-V_{RMS} pop-free stereo line driver designed to allow removal of the output dc-blocking capacitors in audio applications to reduce component count and overall cost. The device is ideal for single-supply electronics where size and cost are critical design parameters.

Designed using TI's patented DirectPath™ technology, the DRV603 is able to drive 2 V_{RMS} into a 2.5-kΩ load with a 3.3-V supply voltage and more than 3 V_{RMS} with a 5-V supply voltage. The device has differential inputs and uses external gain-setting resistors that support a gain range of ±1 V/V to ±10 V/V, and line outputs that have ±8 kV IEC electrostatic discharge (ESD) protection. The DRV603 also has built-in shutdown control for pop-free on/off control.

Using the DRV603 in audio product applications can reduce component counts considerably compared to traditional methods of generating a 2-V_{RMS} to 3-V_{RMS} output. The DRV603 does not require a power supply greater than 3.3 V to generate its 5.6-V_{PP} output or greater than 5 V to generate its 9-V_{PP} output, nor does it require a split-rail power supply. The DRV603 integrates its own charge pump to generate a negative supply rail that provides a clean, pop-free, ground-biased 2-V_{RMS} to 3-V_{RMS} output. The DRV603 is available in a 14-pin TSSOP package.

This EVM is configured with one TOSLINK™ digital audio S/PDIF input and two RCA phono input connectors for analog input; the analog or digital input is selected with pin headers. The pin headers can also be used to feed balanced analog audio into the DRV603. The output signal is available on two RCA phono connectors. The power supply is connected via a two-pin, 2,54-mm header.

This evaluation board is designed for testing applications such as set-top boxes, LCD/PDP TVs, Blu-ray Disc™ DVD players, DVD mini-component systems, home theater-in-a-box (HTIB) systems, or soundcards.

This document presents EVM specifications, audio performance measurements graphs, and design documentation that includes complete circuit descriptions, schematic diagrams, a parts list, and PCB layout design. Gerber (layout) files are available from the TI web site at www.ti.com.

Throughout this document, the abbreviation *EVM* and the term *evaluation module* are synonymous with the DRV603EVM.

1.1 DRV603EVM Features

The DRV603EVM has these features:

- Two-channel evaluation module (double-sided, plated-through PCB layout)
- 2-V_{RMS} line output
- Single-ended or balanced analog input
- Digital S/PDIF TOSLINK input
- No output capacitor required
- Shutdown button

Figure 1 illustrates the functional diagram for the EVM. Table 1 summarizes the key parameters.

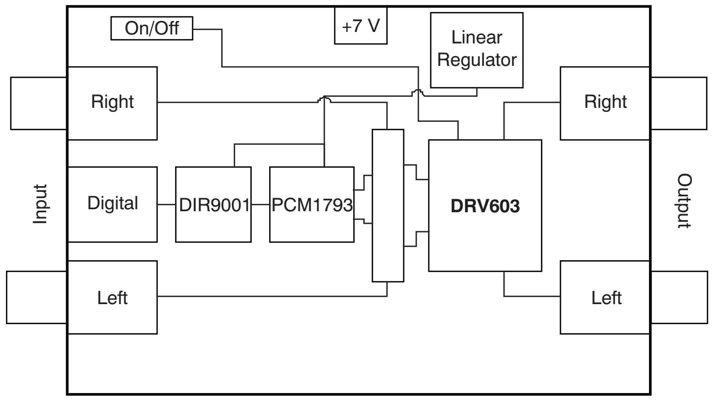

Figure 1. DRV603EVM Functional Block Diagram

Table 1. Key Parameters

Key Parameters	Specification/Unit
Supply Voltage	7 V
Number of Channels	Two
Load Impedance	2.5 kΩ (min)
Output Voltage	3 V_{RMS}
Dynamic Range: Analog Input	> 112 dB
Dynamic Range: Digital Input	> 108 dB

2 Quick Setup

This section describes the DRV603EVM board with regard to the power supply and system interfaces. It provides information about handling and unpacking the DRV603EVM, absolute operating conditions, and a description of the factory default switch and jumper configurations.

The following subsections provide a step-by-step guide to configuring the DRV603EVM for device evaluation.

2.1 Electrostatic Discharge Notice

CAUTION

Many of the components on the DRV603EVM are susceptible to damage by electrostatic discharge (ESD). Customers are advised to observe proper ESD handling precautions when unpacking and handling the EVM, including the use of a grounded wrist strap at an approved ESD workstation.

Failure to observe proper ESD handling procedures may result in damage to EVM components.

2.2 Unpacking the EVM

Upon opening the DRV603EVM package, ensure that the following items are included:

- One DRV603EVM evaluation board, including:
  - One DRV603PW device

If either item is missing, please contact the Texas Instruments Product Information Center nearest you to inquire about a replacement.

2.3 Power-Supply Setup

A single power supply is required to power up the EVM. The power supply is connected to the EVM board using a two-pin, 2,54-mm header (J10). Table 2 lists the recommended supply voltage.

Table 2. Recommended Supply Voltage

Description	Voltage Limitations	Current Requirement	Cable
Power supply	7 V	0.10 A	—

CAUTION

Applying voltages above the limitations given in Table 2 may cause permanent damage to your hardware.

3 On/Off Sequence

For minimum click and pop interference during device power on and power off, the DRV603 Enable pin (pin 5) should be held low, primarily because of pre-charging of the ac-coupled input capacitors. The preferred power-up/-down sequence is shown in Figure 2.

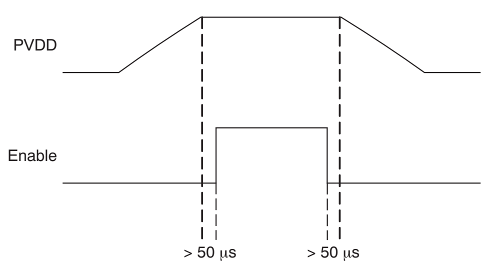

Figure 2. Power-Up/-Down Sequence

This sequence is controlled by the onboard power-supply monitor, U95.

4 Component Selection

4.1 Charge Pump

The charge pump flying capacitor, C13, serves to transfer charge during the generation of the negative supply voltage. The PVSS capacitor must be at least equal to the charge pump capacitor in order to allow a maximum charge transfer. Low equivalent series resistance (ESR) capacitors are an ideal selection, with a typical value of 1 μF. Capacitor values less than 1 μF can be used, but the maximum output can be reduced. It is therefore recommended to validate the design with thorough testing.

4.2 Power-Supply Decoupling Capacitors

The DRV603 is a DirectPath™ line driver amplifier that requires adequate power-supply decoupling to ensure that noise and total harmonic distortion (THD) are low. A good low ESR ceramic capacitor, C12 (1 μF typical), placed as close as possible to the device V_{DD} leads is the best option. Placing this decoupling capacitor close to the DRV603 device is important for amplifier performance. For filtering lower-frequency noise signals, a 10-μF or greater capacitor placed near the audio amplifier may also help, but is not required in most applications because of the high PSRR of the DRV603.

The charge pump circuit does apply ripple current on the V_{DD} line, and an LC or RC filter may be needed if noise-sensitive audio devices share the V_{DD} supply.

4.3 Using the DRV603 as a Differential Input, Second-Order, Low-Pass Filter

Several audio digital-to-audio converters (DACs) used in typical consumer applications require an external low-pass filter to remove out-of-band noise. This function is also possible with the DRV603; the EVM is configured as a 50-kHz, second-order active Butterworth filter to accomplish this filtering using an MFB (Multiple Feed Back) topology with a differential input. Furthermore, the DRV603 requires an ac-coupling capacitor to remove dc content from the source.

The recommended component values can be calculated with the help of the TI FilterPro active filter design program available at http://focus.ti.com/docs/toolsw/folders/print/filterpro.html on the TI web site. Figure 3 illustrates the circuit design for this configuration.

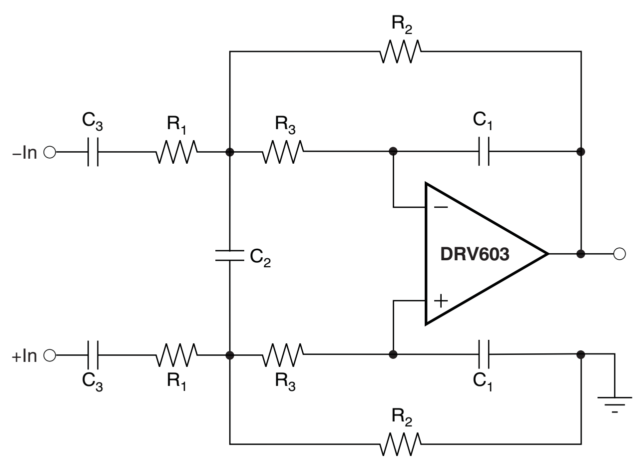

Figure 3. Differential Input, Second-Order, Active Low-Pass Filter

Figure 3 uses the component references also used in the FilterPro software. Various recommendation for filter and gain settings are listed in Table 3.

Table 3. DRV603EVM Filter Specifications

EVM Reference Designators			C23, C27, C28, C32	C25, C30	C24, C26, C29, C31	R23, R24, R29, R30	R22, R27, R28, R33	R25, R26, R31, R32
Gain	**High Pass**	**Low Pass**	**C1**	**C2**	**C3**	**R1**	**R2**	**R3**
–1 V/V	1.6 Hz	40 kHz	100 pF	680 pF	10 µF	10 kΩ	10 kΩ	24 kΩ
–1.5 V/V	1.3 Hz	40 kHz	68 pF	680 pF	15 µF	8.2 kΩ	12 kΩ	30 kΩ
–2 V/V	1.6 Hz	40 kHz	33 pF	150 pF	6.8 µF	15 kΩ	30 kΩ	47 kΩ
–2 V/V	1.6 Hz	30 kHz	47 pF	470 pF	6.8 µF	15 kΩ	30 kΩ	43 kΩ
–3.33 V/V	1.2 Hz	40 kHz	33 pF	470 pF	10 µF	13 kΩ	43 kΩ	43 kΩ
–10 V/V	0.6 Hz	30 kHz	22 pF	1 nF	22 µF	4.7 kΩ	47kΩ	27 kΩ

The resistor values should be low value to achieve low noise, but should be of high enough value to obtain a small size ac-coupling capacitor.

The MFB topology demands a unity-gain stable op amp. If this condition can be relaxed for a specific application, a capacitor from the inverting input to GND of the same value as C_1 can be used. This alternate configuration increases the high-frequency gain to 2.

5 Layout Recommendations

5.1 SGND and PGND Connections

The SGND and GND pins of the DRV603 must be routed separately back to the decoupling capacitor in order to facilitate proper device operation. If the SGND pins are connected directly to each other, the device functions without risk of failure, but noise and THD performance can be reduced.

On the DRV603EVM, a star ground routing pattern is used; the star point is located directly below the DRV603 device itself.

6 DRV603EVM Performance

This section discusses the DRV603EVM overall performance in key parametric areas. Table 4 through Table 8 summarize the EVM specifications.

Note: All electrical and audio specifications are typical values.

Table 4. General Test Conditions[1]

General Test Conditions		Notes
Supply voltage	7.0 V	
Load impedance	2.5 kΩ	
Input signal	1 kHz sine	Digital audio TOSLINK S/PDIF
Measurement filter	AES17	

(1) These test conditions are used for all tests, unless otherwise specified.

Table 5. Electrical Data

Electrical Data		Notes/Conditions
Output voltage, 2500 Ω	3.4 V_{RMS}	1 kHz, THD+N = 1%, T_A = +25°C
Output voltage, 100 kΩ	3.5 V_{RMS}	1 kHz, THD+N = 1%, T_A = +25°C
Supply current	< 90 mA	1 kHz, V_O = 2 V_{RMS}, including linear regulator and LED

Table 6. Audio Performance Analog Input

Audio Performance Analog Input			Notes/Conditions
THD+N, 2.5 kΩ	0.02 V_{RMS}	< 0.070 %	1 kHz (Noise limited)
THD+N, 2.5 kΩ	0.2 V_{RMS}	< 0.007 %	1 kHz (Noise limited)
THD+N, 2.5 kΩ	2 V_{RMS}	< 0.002 %	1 kHz
Dynamic range		> 112 dB	Ref: 2 V_{RMS}, A-weighted, AES17 filter
Noise voltage		< 6 μV_{RMS}	A-weighted, AES17 filter
DC offset		< 1 mV	No signal, 2.5-kΩ load
Channel separation		> 90 dB	1 kHz, 2 V_{RMS}
Frequency response: 20 Hz to 20 kHz		±0.5 dB	2 V_{RMS} / 2.5 kΩ

Table 7. Audio Performance Digital Input

Audio Performance Digital Input			Notes/Conditions
THD+N, 2.5 kΩ	0.02 V_{RMS}	< 0.070 %	1 kHz (Noise limited)
THD+N, 2.5 kΩ	0.2 V_{RMS}	< 0.007 %	1 kHz (Noise limited)
THD+N, 2.5 kΩ	2 V_{RMS}	< 0.002 %	1 kHz
Dynamic range		> 109 dB	Ref: 2 V_{RMS}, A-weighted, AES17 filter
Noise voltage		< 9 μV_{RMS}	A-weighted, AES17 filter
DC offset		< 1 mV	No signal, 2.5-kΩ load
Channel separation		> 90 dB	1 kHz, 2 V_{RMS}
Frequency response: 20 Hz to 20 kHz		±0.5 dB	2 V_{RMS} / 2.5 kΩ

Table 8. Physical Specifications

Physical Specifications		Notes/Conditions
PCB dimensions	70 × 70 × 25 mm	Width × Length × Height (mm)
Total weight	40 g	Components + PCB + Mechanics

6.1 THD+N versus Voltage

Up to approximately 1 V_{RMS}, THD+N is dominated by the noise element for both the analog input and the digital input, respectively, as shown in Figure 4 and Figure 5. 0.001% equals –100 dB for both graphs.

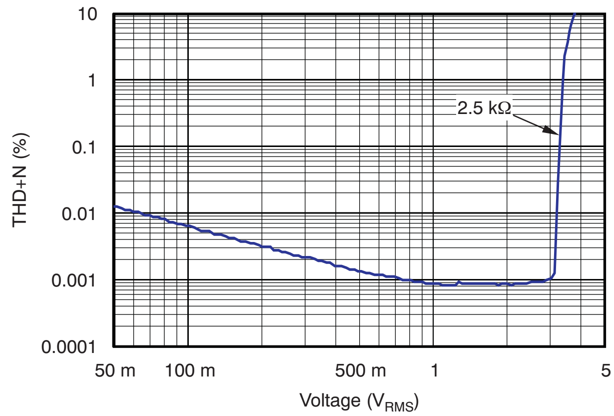

Figure 4. THD+N versus Voltage (Analog Input)

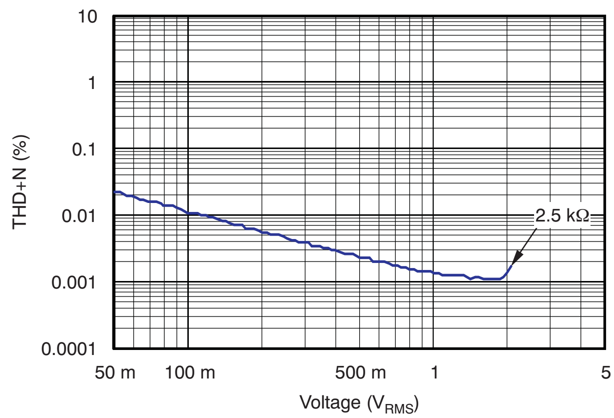

Figure 5. THD+N versus Voltage (Digital Input)

6.2 THD+N vs Frequency

Figure 6 and Figure 7 illustrate characteristic performance for THD+N versus frequency.

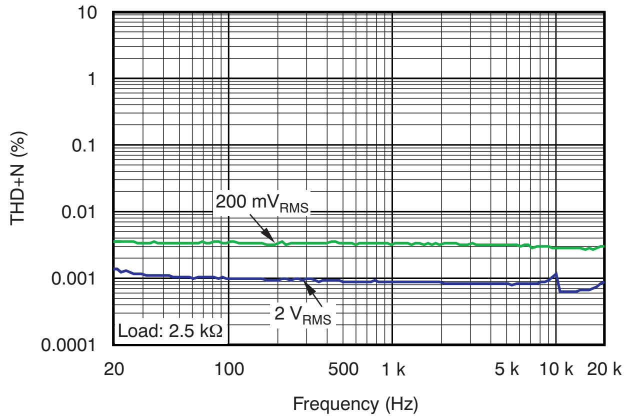

Figure 6. THD+N versus Frequency (Analog Input)

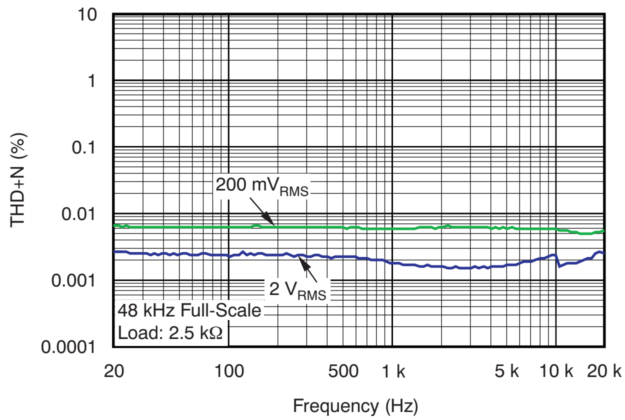

Figure 7. THD+N versus Frequency (Digital Input, 0 dBFS)

6.3 FFT Spectrum with –60dBFS Tone

For the FFT plot shown in Figure 8, the reference voltage is 3 V_{RMS} and the FFT size is 16 k.

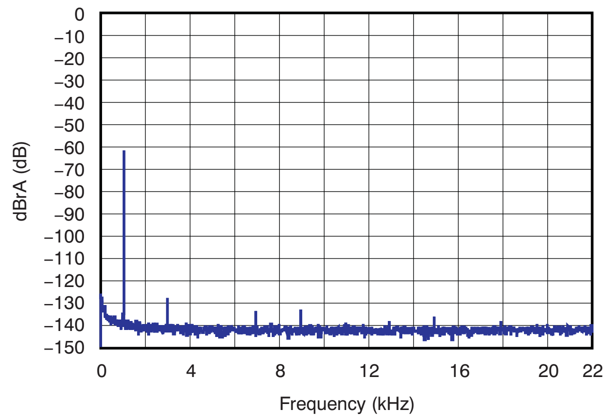

Figure 8. FFT Spectrum with –60-dBFS Tone (Analog Input)

For the FFT plot shown in Figure 9, the reference voltage is 2.1 V_{RMS} and the FFT size is 16 k.

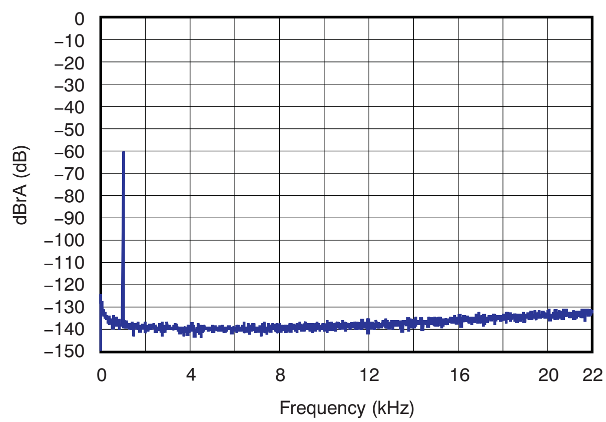

Figure 9. FFT Spectrum with –60-dBFS Tone (Digital Input)

For both FFT plots, the digital input, noise, and dynamic range are: 7.7 µV_{RMS}, 108.5 dB referenced to 2.1 V_{RMS}, A-weighted.

6.4 Idle Noise FFT Spectrum

For both analog and digital inputs, as shown in Figure 10 and Figure 11 respectively, the reference voltage is 2 V_{RMS} and the FFT size is 16 k.

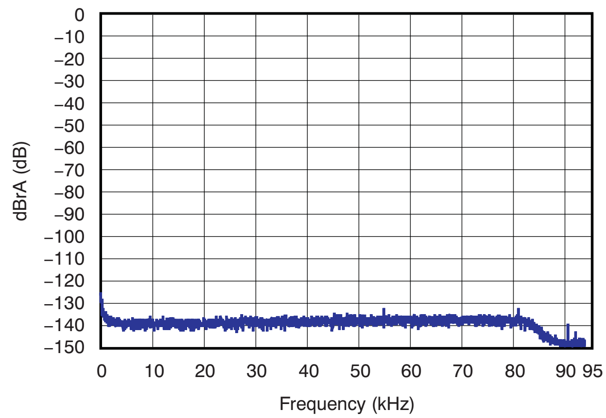

Figure 10. Idle Noise FFT Spectrum (Analog Input)

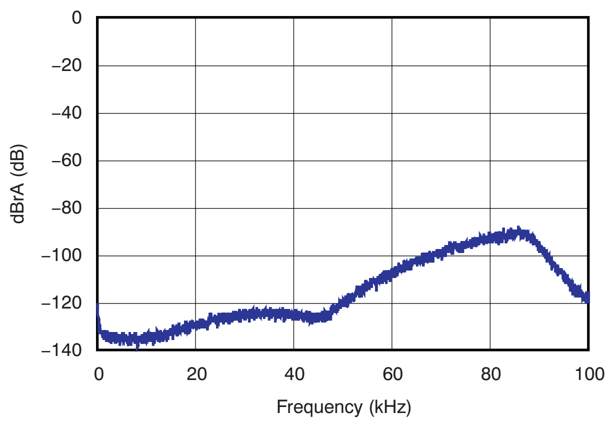

Figure 11. Idle Noise FFT Spectrum (Digital Input)

6.5 Channel Separation

Figure 12 illustrates the channel separation for the analog input. Figure 13 shows the channel separation for the digital input.

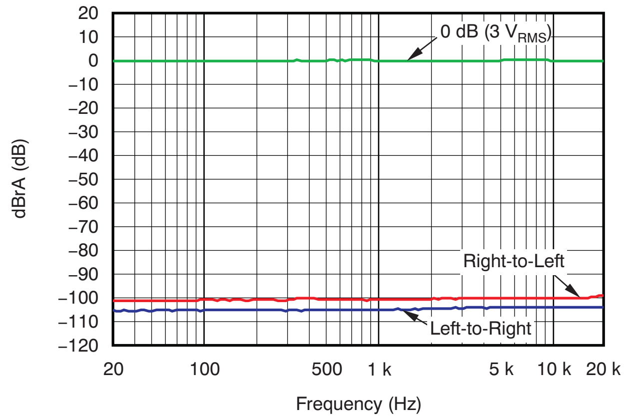

Figure 12. Channel Separation (Analog Input)

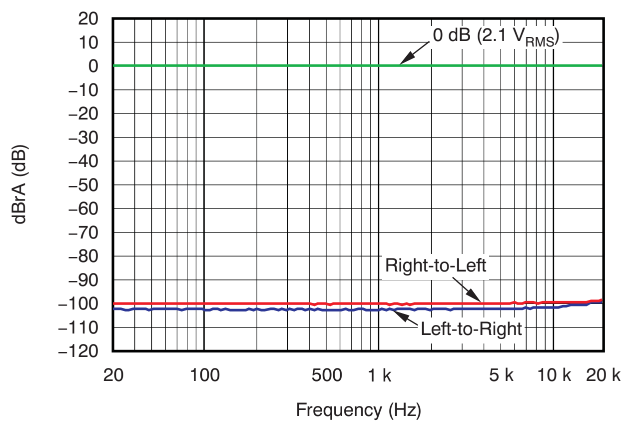

Figure 13. Channel Separation (Digital Input)

6.6 Frequency Response

Figure 14 and Figure 15 show the frequency response for the analog and digital inputs, respectively.

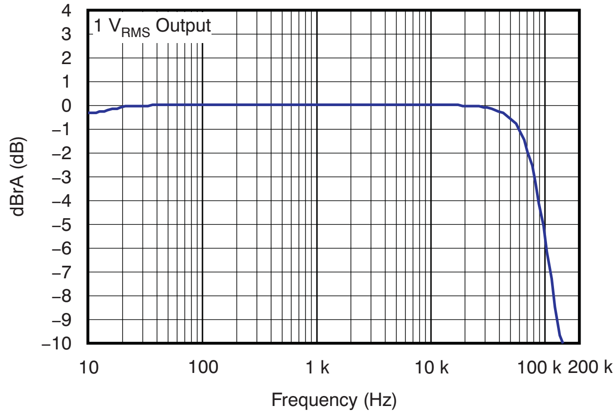

Figure 14. Frequency Response (Analog Input)

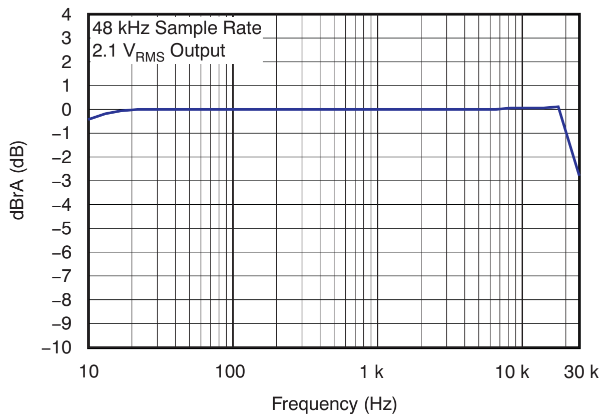

Figure 15. Frequency Response (Digital Input)

6.7 Pop/Click (Enable)

The characteristic performance for pop and click interference is shown with and without an input signal applied, with a load of 2.5 kΩ. Measurement results are presented in a time domain format.

For Figure 16, the power supply is applied, and then the shutdown signal is released. The shutdown signal triggers the measuring system.

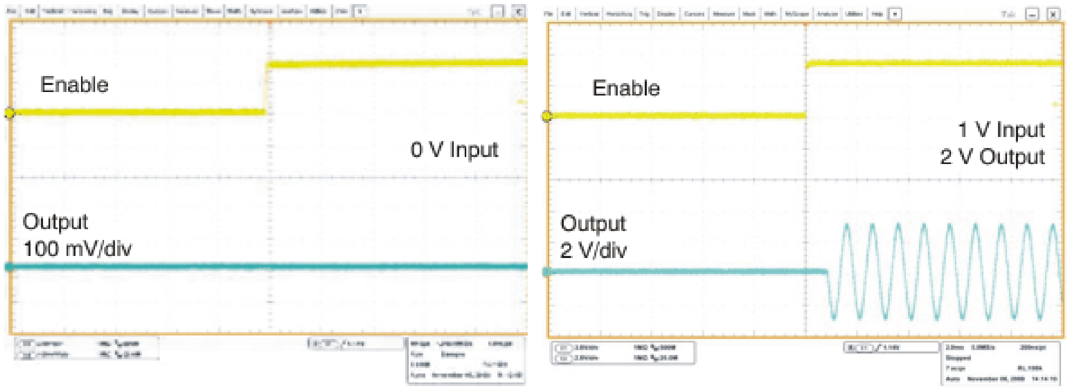

Figure 16. Pop/Click (Enable)

6.8 Pop/Click (Disable)

As with Section 6.7, characteristic performance for pop and click interference is shown with and without an input signal applied, with a load of 2.5 kΩ. Measurement results are again presented in a time domain format.

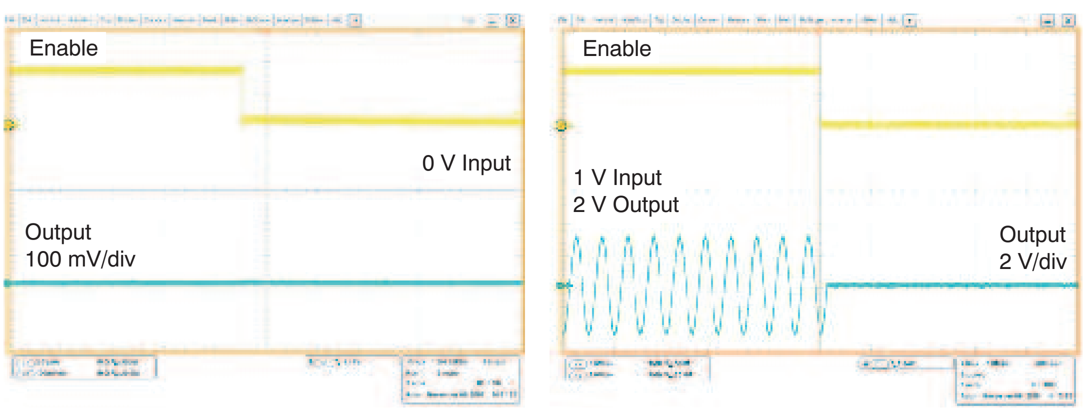

Figure 17. Pop/Click (Disable)

7 Related Documentation from Texas Instruments

The following related documents are available through the Texas Instruments web site at http://www.ti.com.These documents have detailed descriptions of the integrated circuits used in the design of the DRV603EVM.

Table 9. Related Documentation

Part Number	Literature Number
DRV603	SLOS617
DIR9001	SLLS843
PCM1789	SBAS451
TPS3825-33	SLVS165
TLV1117-50	SLVS561
TLV1117-33	SLVS561

8 Design Documentation

8.1 Schematics

Line Driver

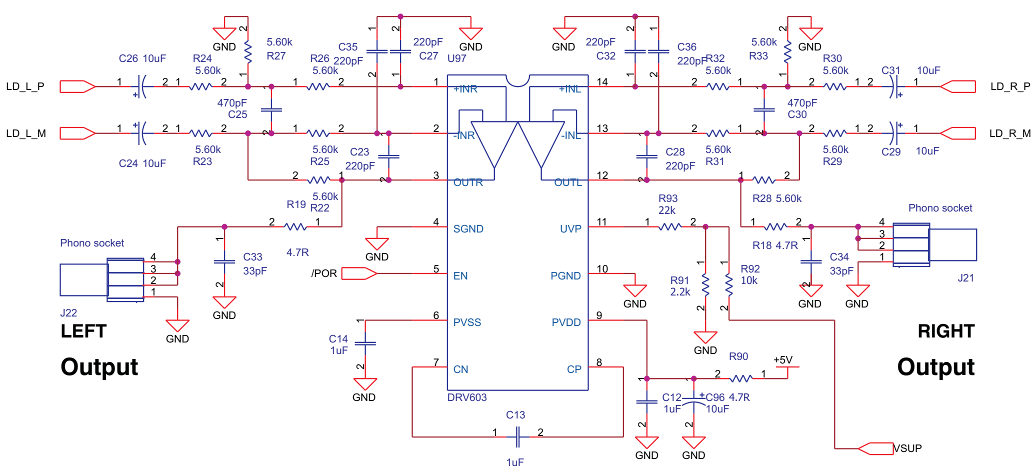

Figure 18. DRV603EVM Schematic: DRV603

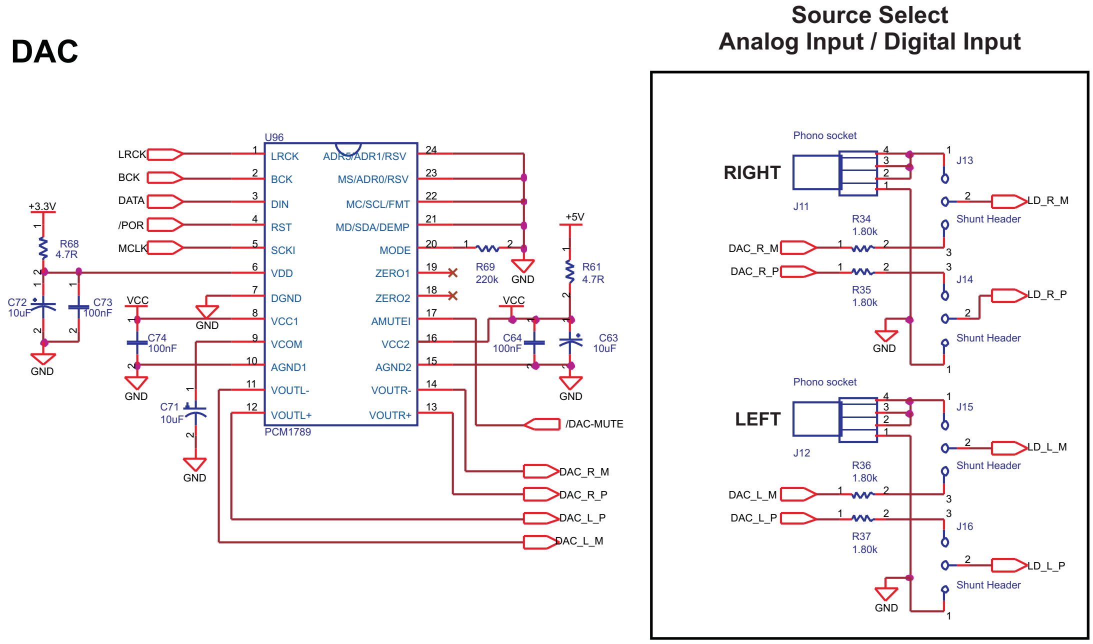

Figure 19. DRV603EVM Schematic: Digital-to-Analog Converter and Source Select

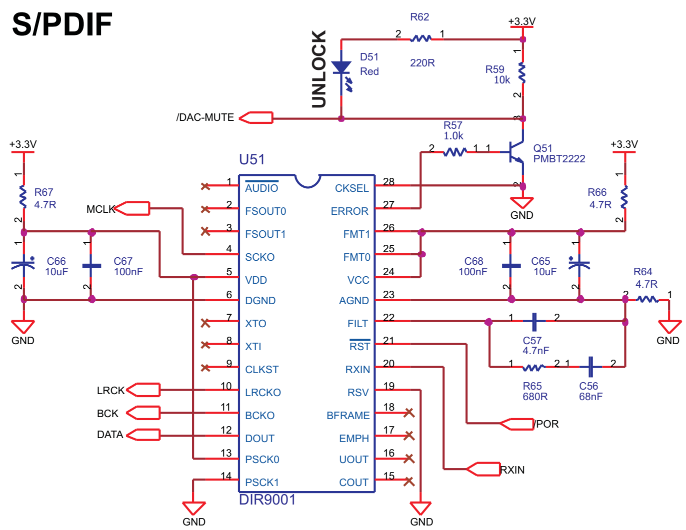

Figure 20. DRV603EVM Schematic: S/PDIF Receiver

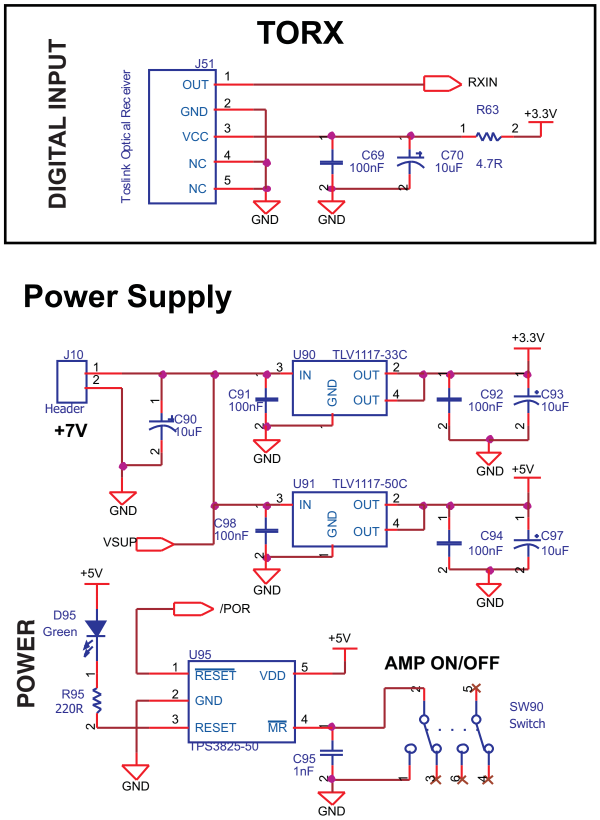

Figure 21. DRV603EVM Schematic: TOSLINK and Power Supply

8.2 Parts List

The bill of materials (BOM) for the DRV603EVM is listed in Table 10.

Table 10. Bill of Materials

Qty	Part Reference	Description	Manufacturer	Mfr Part No
3	C12, C13, C14	Ceramic 1 µF / 16 V / 20% X7R 0805 Capacitor	BC Components	0805B105M160NT
6	C23, C27, C28, C32, C35, C36	Ceramic 220 pF / 50 V / 10% NP0 0603 Capacitor	BC Components	0603N221K500NT
14	C24, C26, C29, C31, C63, C65, C66, C70, C71, C72, C90, C93, C96, C97	Electrolytic 10 µF / 16 V / 20% Aluminium 2 mm ×5 mm M Series - General Purpose Capacitor	Panasonic	ECA1CM100
2	C25, C30	Ceramic 470 pF / 50 V / 10% NP0 0805 Capacitor	BC Components	0805N471K500NT
2	C33, C34	Ceramic 33 pF / 50 V / 10% NP0 0603 Capacitor	BC Components	0603N330K500NT
1	C56	Ceramic 68 nF / 16 V / 20% X7R 0603 Capacitor	BC Components	0603B683M160NT
1	C57	Ceramic 4.7 nF / 50 V / 20% X7R 0603 Capacitor	BC Components	0603B472M500NT
5	C64, C67, C68, C73, C74	Ceramic 100 nF / 50 V / 20% X7R 0603 Capacitor	Vishay	VJ0603Y104MXA
5	C69, C91, C92, C94, C98	Ceramic 100 nF / 16 V / 20% X7R 0603 Capacitor	Vishay	VJ0603Y104MXJ
1	C95	Ceramic 1 nF / 50 V / 10% NP0 0603 Capacitor	BC Components	0603N102K500NT
1	D51	Light Emitting Red Red LED (0603)	Toshiba	TLSU1008
1	D95	Light Emitting Green Green LED (0603)	Toshiba	TLGU1008
1	J10	2 pins / 1 row / 2.54-mm Pitch Vertical Male Friction Lock Pin Header	Molex	22-27-2021
4	J11, J12, J21, J22	Horizontal Female with Switch Coax Phono Socket	Chunfeng	RJ843-4W
4	J13, J14, J15, J16	3 pins / 1 row / 2.54-mm Pitch Vertical Male Shunt Header	Samtec	TSW-107-07-T-T
1	J51	Toslink Optical Receiver, Toslink Receiver, 3.3 V Special Function	Toshiba	TORX147PL
4	JUMPER13, JUMPER14, JUMPER15, JUMPER16	2 pins / 1 row / 2.54-mm Pitch Horizontal Female Black Shunt	Molex	15-29-1024
1	PCB11	A852-PCB-001_2.00 / DRV603EVM Printed Circuit Board (ver. 2.00)	Printline	A852-PCB-001(2.00)
1	Q51	600 mA / 40 V NPN Small-signal PMBT2222 Transistor (SOT-23)	Philips	PMBT2222
9	R18, R19, R61, R63, R64, R66, R67, R68, R90	4.7 R / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-074R7L
12	R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33	5.60 k / 100 mW / 1% / 0603 Thick Film Resistor	Yageo	RC0603FR-075K6L
4	R34, R35, R36, R37	1.80 k / 100 mW / 1% / 0603 Thick Film Resistor	Yageo	RC0603FR-071K8L
1	R57	1.0 k / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-071KL
2	R59, R92	10 k / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-0710KL
2	R62, R95	220 R / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-07220RL
1	R65	680 R / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-07680RL

Table 10. Bill of Materials (continued)

Qty	Part Reference	Description	Manufacturer	Mfr Part No
1	R69	220 k / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-07220KL
1	R91	2.2 k / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-072K2L
1	R93	22 k / 100 mW / 5% / 0603 Thick Film Resistor	Yageo	RC0603JR-0722KL
1	SW90	Switch DPDT PCB Mount Switch	NKK-Nikkai	G-22-AP
1	U51	DIR9001 / 96-kHz Digital Audio Receiver (TSSOP28)	Texas Instruments	DIR9001PW
1	U90	TLV1117-33C / 3.3-V / 800-mA Positive Voltage Regulator (SOT4-DCY)	Texas Instruments	TLV1117-33CDCYR
1	U91	TLV1117-50C / 5.0-V / 800-mA Positive Voltage Regulator (SOT4-DCY)	Texas Instruments	TLV1117-50CDCYR
1	U95	TPS3825-50 / 5.0-V Supply Voltage Supervisor (SOP5-DBV)	Texas Instruments	TPS3825-50DBVT
1	U96	PCM1789 / 24-Bit, 192-kHz, Enhanced Multi-Level Delta-Sigma, Audio Stereo DAC (TSSOP24-PW)	Texas Instruments	PCM1789PW
1	U97	DRV603 / DirectPath™ Differential Audio Line Driver with ext. gain setting and UVP (TSSOP14-PW)	Texas Instruments	DRV603PW

8.3 PCB Specification

Table 11 summarizes the specifications for the evaluation board PCB.

Table 11. PCB Specifications

Board Identification	A852-PCB-001(2.00)
Board type	Double-sided plated-through board
Laminate type	FR4
Laminate thickness	1,0 mm
Copper thickness	35 µm (including plating exterior layers)
Copper plating of holes	> 25 µm
Minimum hole diameter	0,3 mm
Silkscreen, component side	White; remove silkscreen from solder and pre-tinned areas
Silkscreen, solder side	None
Soldermask, component side	Green
Soldermask, solder side	Green
Protective coating	Solder coating and chemical silver on free copper
Electrical test	PCB must be electrically tested
Manufactured to	PERFAG 2E (www.perfag.dk)
Aperture table	PERFAG 10A (www.perfag.dk)
Board dimensions	60 mm x 90 mm

8.4 PCB Layers

Gerber files are available for download at the DRV603EVM product folder page on the TI web site. Component placement and board layout are illustrated in Figure 22, Figure 23, and Figure 24, respectively.

Note: Board layouts are not to scale. These figures are intended to show how the board is laid out; they are not intended to be used for manufacturing DRV603EVM PCBs.

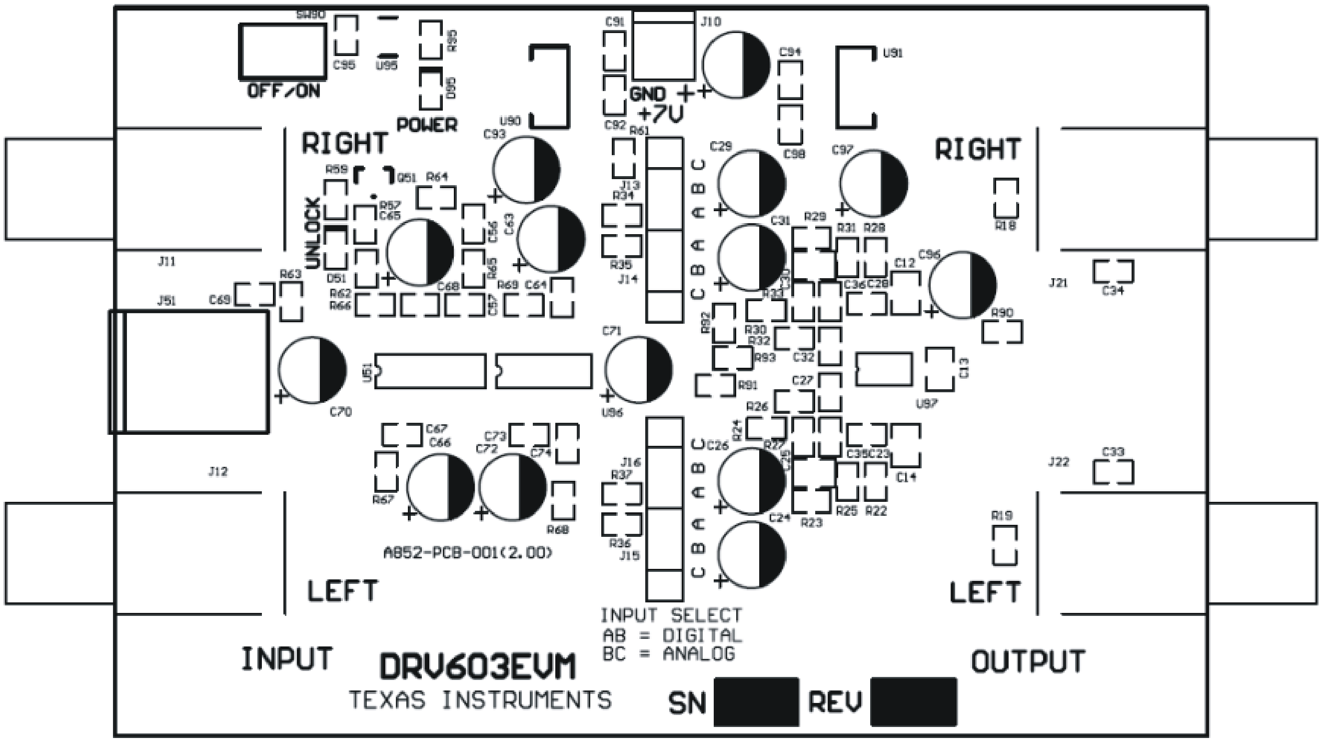

Figure 22. DRV603EVM PCB Component Placement

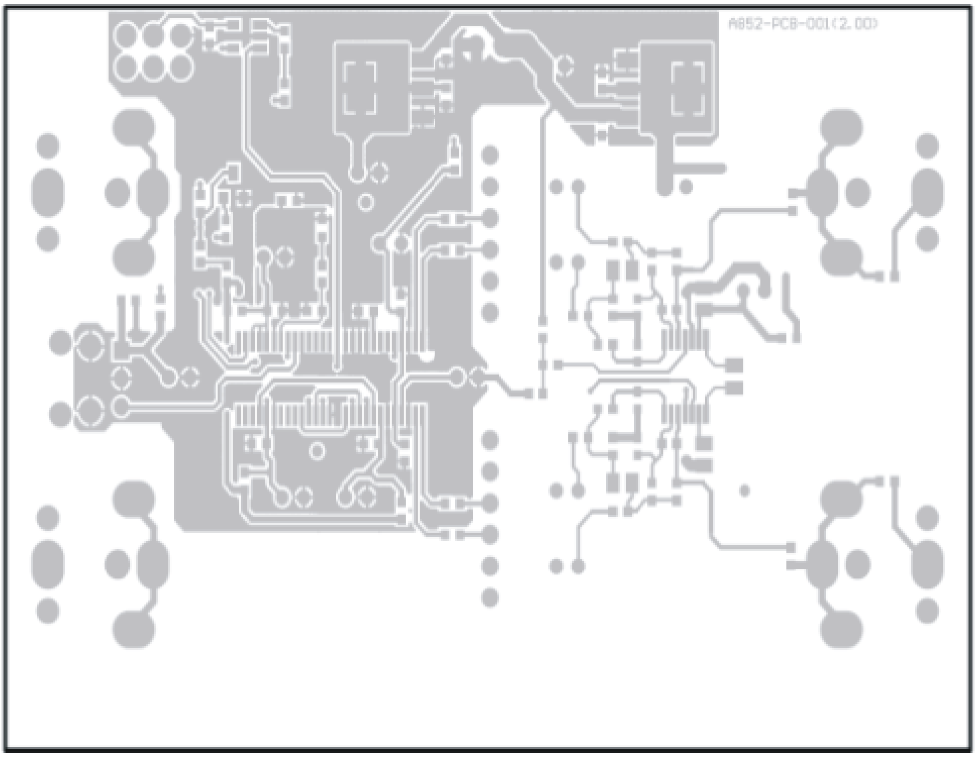

Figure 23. DRV603EVM PCB Top Layer

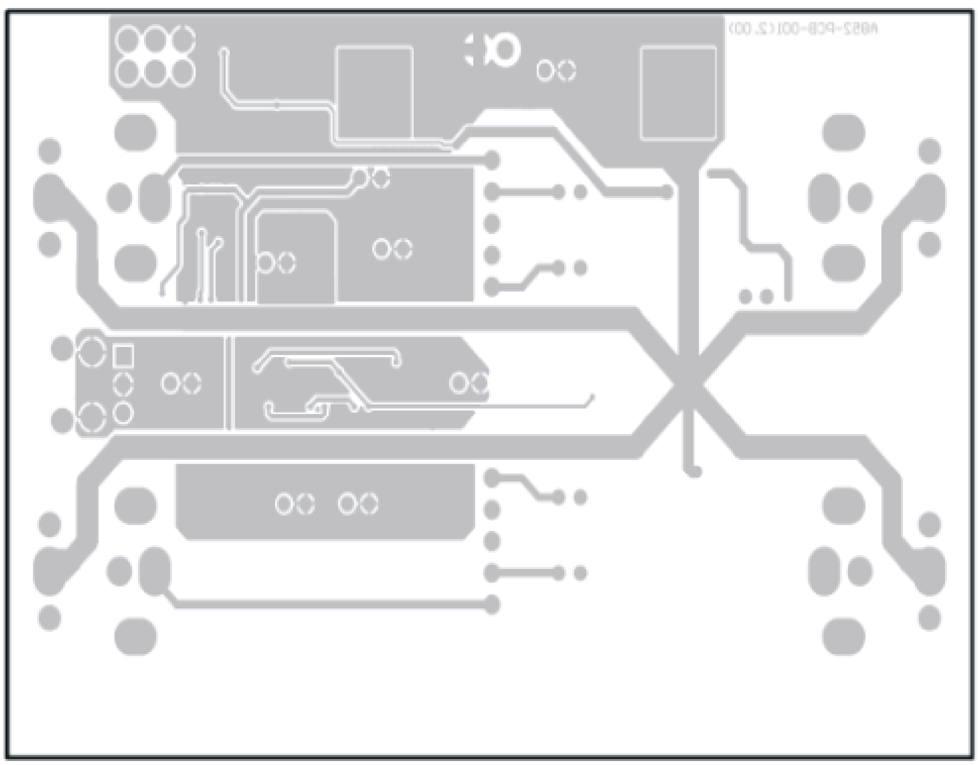

Figure 24. DRV603EVM PCB Bottom Layer

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 0 V to 3 V_{RMS} and the output voltage range of 0 V to 3.3 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than +60°C. The EVM is designed to operate properly with certain components above +40°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265