TI Designs

Using LMH6521 in DC-Coupled Applications Design Guide

TI Designs

TI Designs are analog solutions created by TI's analog experts. Reference designs offer the theory, component selection, and simulation of useful circuits. Circuit modifications that help to meet alternate design goals are also discussed.

Design Resources

TIDA-00383	Tool Folder Containing Design Files
TINA-TI™	Product Folder
LMH6521	Product Folder

Circuit Description

This design shows the application of a DC-capable circuit for the LMH6521. This design is appropriate for DC-coupled circuits and applications where the signal path is close to DC, such as zero IF.

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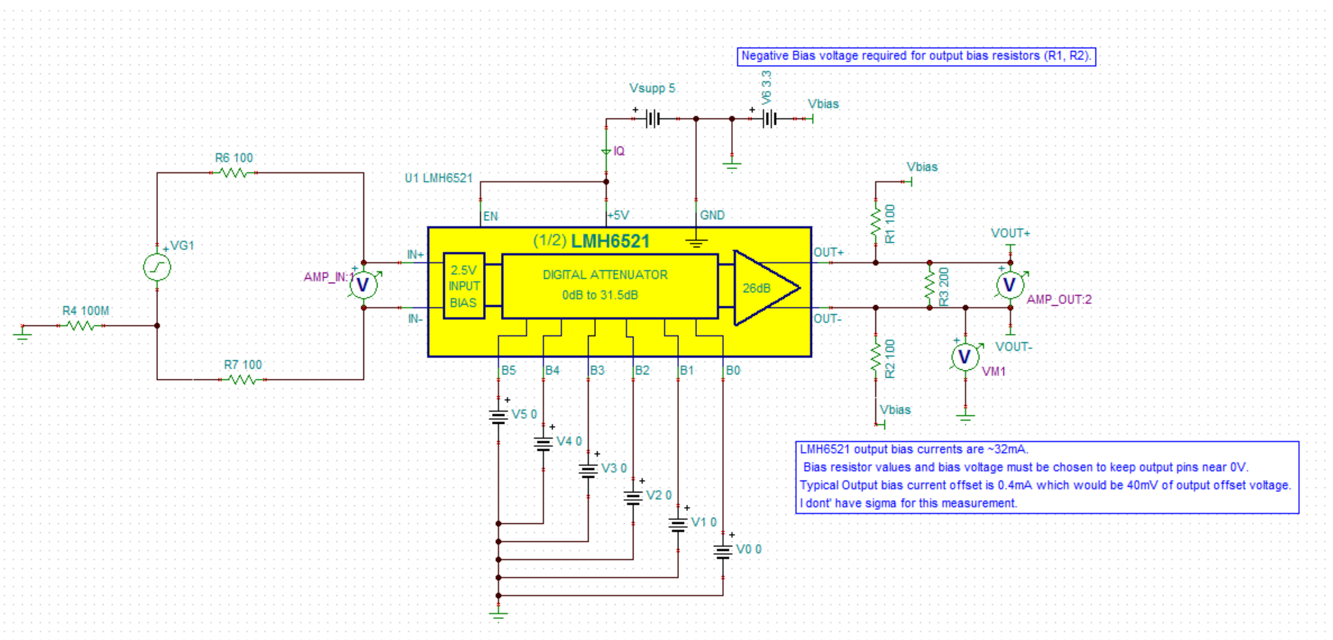

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1 Design Sumary

- Supply voltage: 5 V and –3 V
- Supply current: 300 mA
- Output common-mode voltage: 0 V ± 0.5 V
- Maximum gain: 26 dB

A valid DC-coupled operation is achievable with the LMH6521; however, the setup requires significant care in the system design. The input of the LMH6521 is self-biased to 2.5 V. Devices connected to the LMH6521 input must be configured to preserve this voltage level. The biggest practical challenge for a DC-coupled operation of the LMH6521 involves the output of the device. This paper describes some of the possible issues involved with using the LMH6521 in DC-coupled applications and offers solutions.

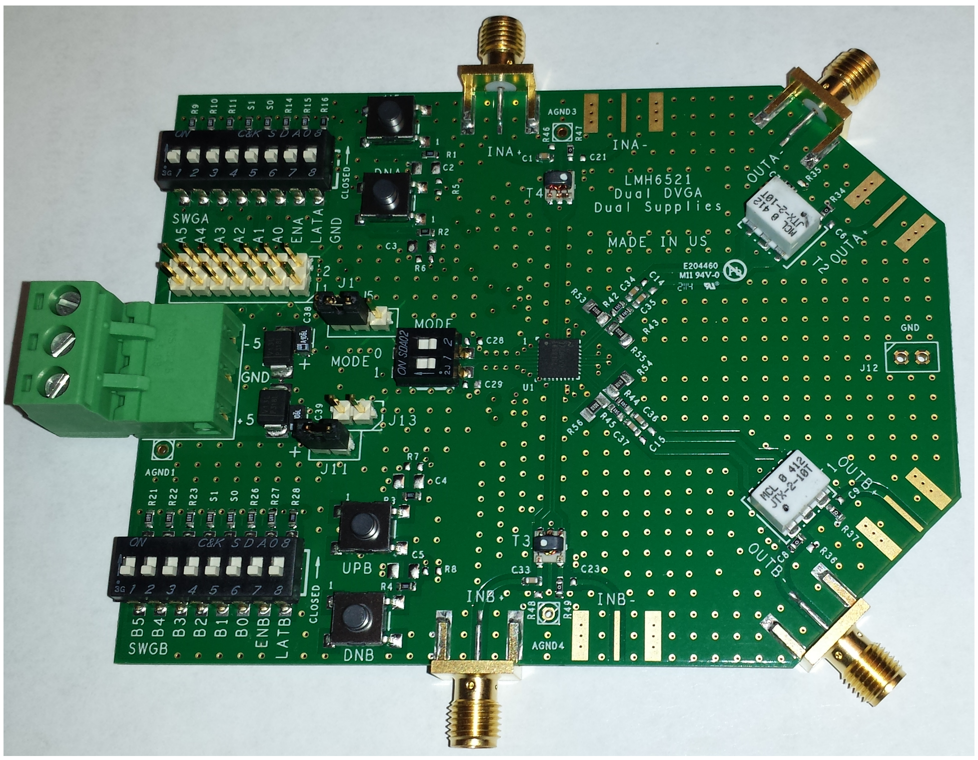

Figure 1. LMH6521 DC-Coupled Design Board

The evaluation board shown in Figure 1 has input and output baluns to evaluate harmonic distortion and intermodulation distortion. The baluns were removed for the frequency response measurement shown in Figure 2.

2 Theory of Operation

The LMH6521 device design offers phenomenal distortion performance and a large output swing from a single 5-V supply. To gain this performance, users must bias the output devices. For best performance, use a bias voltage of 0 V; however, a higher bias voltage will offer some advantages at the expense of device performance. Table 1 and Table 2 show the bias conditions for 0 V and 1 V respectively. The maximum output swing at the 0-V bias condition is 11 Vpp; it is 9 Vpp when the outputs are biased to 1 V.

For AC-coupled applications, this biasing is easily accomplished with RF chokes or inductors. Using RF chokes or inductors to bias the output stage does not allow for DC-coupled applications.

2.1 Equations

In the example, 100-Ω bias resistors are selected to provide a good balance between amplifier loading and a reasonable negative supply voltage. The bias voltage of –3.3 V is very close to the predicted voltage of –3.6 V based on the datasheet bias current value of 0.036 A. For design purposes, select the negative supply voltage such that the negative supply = –R × 0.036 A.

$$V_{NegativeSupply} = R_{Bias} \times 0.036\ \text{A} \quad (1)$$

Table 1. Bias Resistor Selection for 0-V Output Common Mode

BIAS RESISTOR	BIAS VOLTAGE	BIAS POWER
50	–1.8	65 mW
100	–3.6	130 mW
200	–7.2	260 mW
> 200	Not recommended	

Table 2. Bias Resistor Selection for 1-V Common Mode

BIAS RESISTOR	BIAS VOLTAGE	BIAS POWER
50	–0.8	13 mW
100	–2.6	68 mW
200	–6.2	192 mW

Overall, the 100-Ω resistors offer a great balance of output impedance for the amplifier, power consumption in the bias resistors, and performance of the amplifier. Slightly better distortion performance is achievable with the 200-Ω resistors, but with a significant increase in power.

3 Designing for DC-Coupled Operation

The LMH6521 output stage is a PNP, open collector output. This type of output stage indicates that there is a bias current flowing out of the device, and that modulation of this current provides the output voltage. If there is no output current the output transistors saturate and float to 5 V. The standard configuration for the LMH6521 device is to be biased with inductors that provide a DC path for the bias currents while providing virtually no load condition for the high-frequency signal.

For DC-coupled operation, the inductors must be removed and an alternate method for providing bias current to the output devices must be arranged. The most obvious method is to select a small-value resistor to take the place of the inductor. This method has been tested in the lab and has several drawbacks, such as a lower available output swing and degraded distortion. The method that this user document details is a similar variant that does use resistors.

To fully utilize the LMH6521 output capabilities, the device must be biased close to 0 V. To achieve this biasing with resistors of realistic values there must be a negative supply voltage available. The LMH6521 is a dual amplifier and each output pin sources 36 mA. The negative power supply must be able to sink 128 mA of current. To cover process variations and temperature fluctuations, use a 200-mA supply. While the current requirements of the negative supply are fixed, the voltage requirement is not. The system design most likely dictates that the LMH6521 device drive a matched load with a value between 100 to 500 Ω. Because the resistive bias sets up a parallel load, avoid lower values of load impedance. The example circuit is set up for a matched load of 200 Ω. This means that the amplifier drives a total load of 100 Ω, which is slightly below the optimal load conditions for this amplifier.

As shown in the example circuit, there is a –3.3-V source connected to two 100-Ω bias resistors for each channel of the LMH6521 (only one channel is shown). An analysis of the DC operation point shows that these connections provide each output with a voltage of 18 mV, which is almost ideal. The goal of the design is to bias the outputs within the range of –0.25 V to +0.25 V.

As shown in Figure 2 the response of the modified evaluation module (EVM) has a flat frequency response at low frequencies.

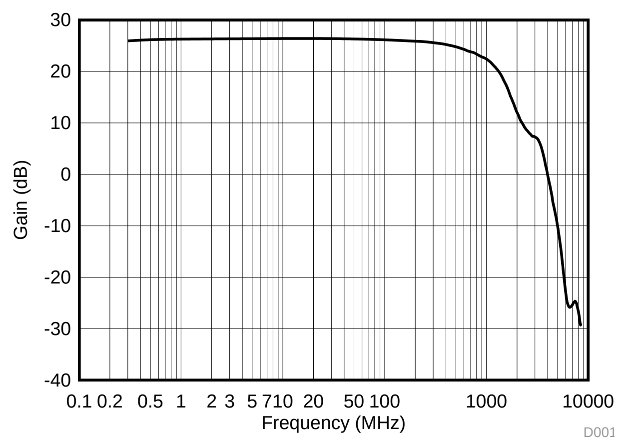

Figure 2. DC-Coupled Frequency Response

4 Simulation

The plot in Figure 3 is the transient response. Because the amplifier is differential, the output signal has no DC information in the plot and always shows a 0-V reference (unless the balance error is excessive). When evaluating the DC performance of a differential amplifier, it is useful to plot one (or both) of the outputs as single-ended. This is shown by the trace VM1 in the plot. This plot confirms that the LMH6521 outputs are operating near 0 V as is required for optimum performance.

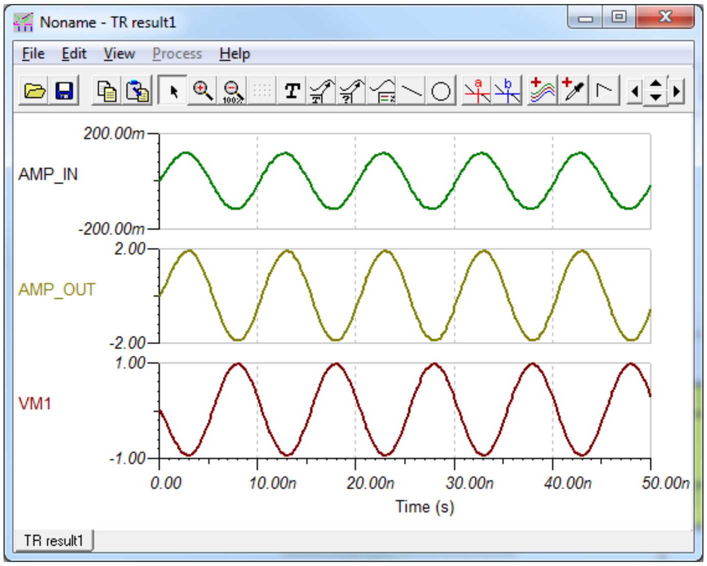

Figure 3. TINA-TI Transient Simulation (VM1 Shows OUT- With DC Information)

The next transient plot in Figure 4 shows the amplifier with no output bias voltage—the resistors are biased to ground (note that this behavior is not correctly modeled in the default LMH6521 TINA model. The default TINA model outputs must be biased to within 0.25 V of ground for proper model operation. An easy modification to the default TINA model will allow for a more accurate modeling of the output bias currents, shown in Figure 5.

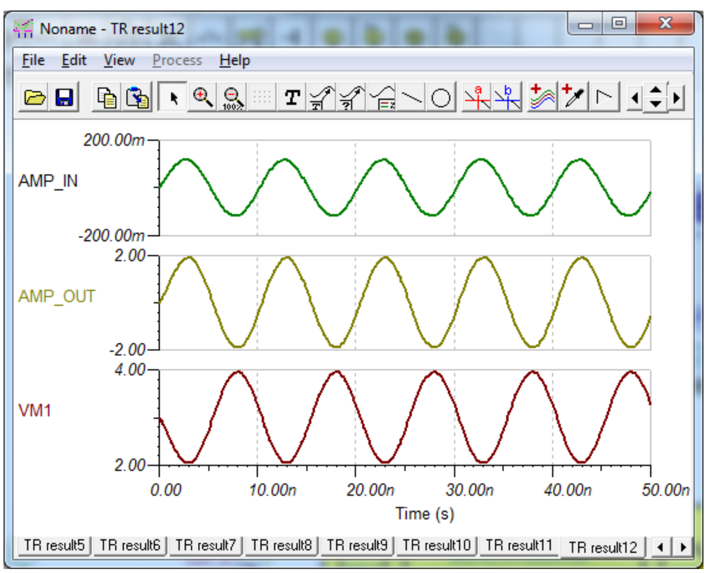

Figure 4. Transient Response—Wrong DC Bias Point

Simulations in TINA show that distortion is probably not accurately modeled. After simulating with and without a negative bias voltage, the DC operating point was not accurately reflected. There is also no evidence of saturation of the output devices. These results indicate that the LMH6521 TINA model is only accurate for small to moderate signal levels and only for DC operating points that place the output pins within 0.25 V of ground.

A simple change to the TINA model allows for accurate modeling of the DC operating point. This is shown in the modified TINA model in Figure 5. AC simulations also work with this model because the 10-F capacitors and the infinite-impedance current sources have no impact on the AC signal path.

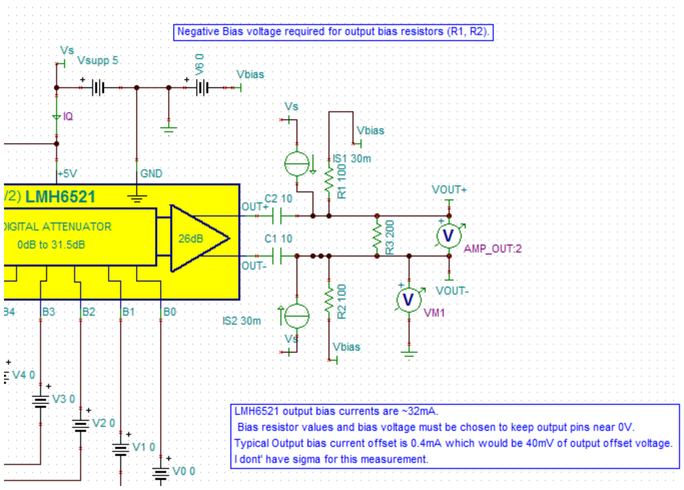

Figure 5. Modified TINA Model for DC Operating Point With Negative Bias Voltage

5 Measured Results

The reference design is built and tested for bandwidth and distortion. The bandwidth is shown in Figure 2. The distortion results are shown in Table 3 and Table 4. The bias resistors are 100 Ω, which means the initial load was 200 Ω. The application load is in parallel with the bias resistors, which makes the net load lower. In the measured data for Table 3, the application load is 100 Ω, while the application load for the data in Table 4 is 180 Ω.

Table 3. Measured Distortion for RLoad = 67 Ω

FREQUENCY	Vpp	HD2	HD3
50 mHz	1 Vpp	–86	–86
	2 Vpp	–83	–88
200 mHz	1 Vpp	–69	–82
	2 Vpp	–63	–71

Table 4. Measured Distortion for RLoad = 95 Ω

FREQUENCY	Vpp	HD2	HD3
50 mHz	1 Vpp	–80	–80
	2 Vpp	–81	–86
200 mHz	1 Vpp	–71	–80
	2 Vpp	–66	–75

6 Board Schematics

The schematics for the reference design are shown in Figure 6 and Figure 7. The signal path is identical to the standard LMH6521 evaluation module except for the bias resistors and bias resistor decoupling capacitors.

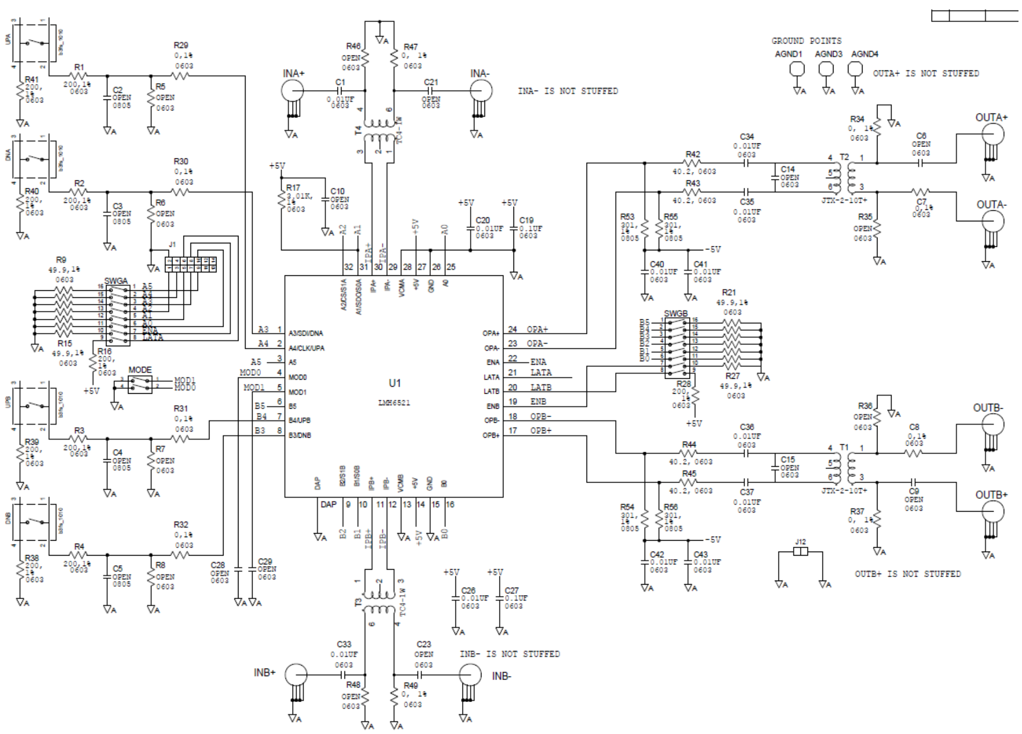

Figure 6. Signal Path Schematic

The negative power supply is set up for maximum flexibility, so there is the option for an external bench supply or an on-board –3.3-V switching regulator. Referring to Figure 7 and Figure 8: To use the on-board regulator, set the jumper on J5 to connect pins 2 and 3. Setting the jumper on J5 to connect pins 1 and 2 sends power from the board-edge power connector to the bias resistors.

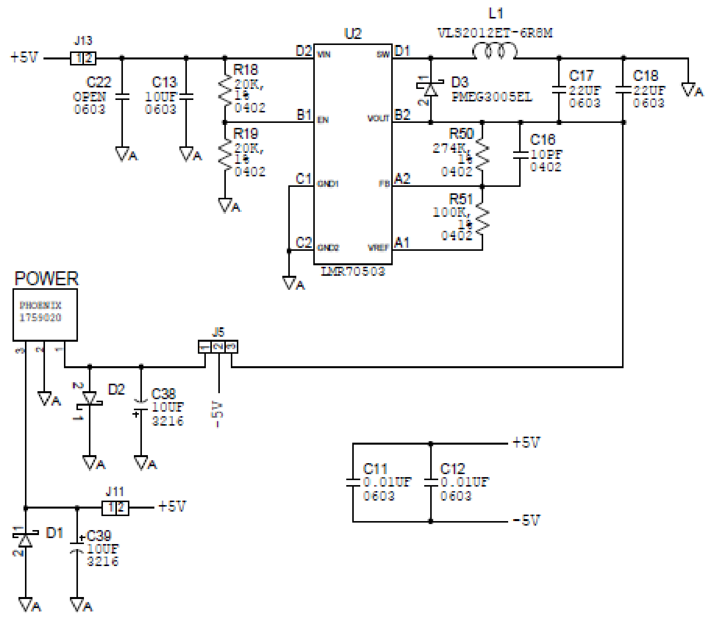

Figure 7. Negative Power Supply Schematic

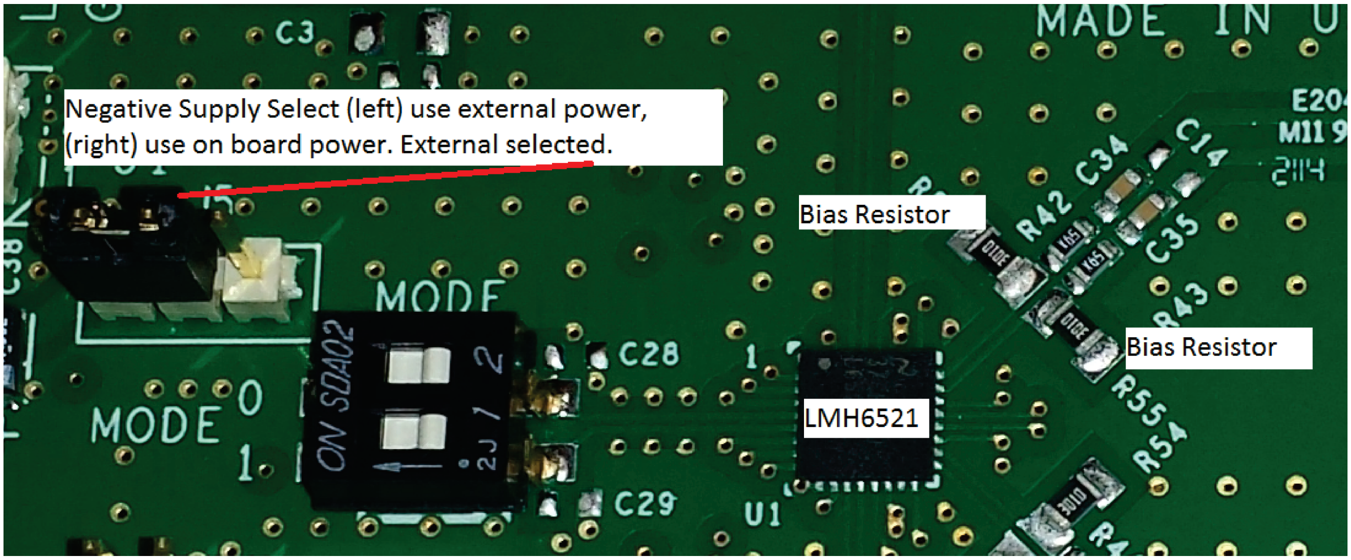

Figure 8. Close-Up of Design Board

7 BOM

To download the bill of materials (BOM), see the design files at TIDA-00383.

Table 5. BOM

MANUFACTURER	PART NUMBER	QUANTITY	DIGIKEY PN	MOUSER PN	NEWARK PN	DESIGNATOR	DESCRIPTION	VALUE
-	-	3	Digikey Order	Mouser Order	Newark Order	AGND1, AGND3, AGND4	-	
Panasonic	06035C103KAT2A	14	Digikey Order	Mouser Order	Newark Order	C1, C11, C12, C20, C26, C33-C37, C40-C43	CAP 10000 PF 50 V CERM X7R 0603	0.01 µF
-	-	14	Digikey Order	Mouser Order	Newark Order	C2-C6, C9-C10, C14, C15, C21-C23,C28, C29	-	-
TDK Corporation	C1608X5R1A106M080 AC	1	Digikey Order	Mouser Order	Newark Order	C13	CAP CER 10 µF 10 V 20% X5R 0603	10 µF
Kemet	C0402C100J5GACTU	1	Digikey Order	Mouser Order	Newark Order	C16	CAP CER 10 PF 50 V 5% NP0 0402	10 pF
TDK Corporation	C1608X5R0J226M080 AC	2	Digikey Order	Mouser Order	Newark Order	C17, C18	CAP CER 22 µF 6.3 V 20% X5R 0603	22 µF
Kemet	C0603X104K3RACTU	2	Digikey Order	Mouser Order	Newark Order	C19, C27	CAP CER 0.1 µF 25 V 10% X7R 0603	0.1 µF
Vishay Sprague	293D106X9010A2TE3	2	Digikey Order	Mouser Order	Newark Order	C38, C39	CAP TANT 10 µF 10 V 10% 1206	10 µF
Panasonic	ERJ-3GEY0R00V	10	Digikey Order	Mouser Order	Newark Order	C7, C8, R29-R32, R34, R37, R47,R49	RES 0.0 Ω 1/10 W Jump 0603 SMD	0.0 Ω
Vishay/Semiconductors	VS-STPS1L30UPBF	2	Digikey Order	Mouser Order	Newark Order	D1, D2	Diode Schottky 30 V 1 A DO214AA	-
NXP Semiconductors	PMEG3005EL,315	1	Digikey Order	Mouser Order	Newark Order	D3	Diode Schottky 30 V 0.5 A SOD882	-
Omron Electronics Inc-EMC Div	B3FS-1010P	4	Digikey Order	Mouser Order	Newark Order	DNA, DNB, UPA, UPB	Switch Tactile Spst-No 0.05 A 24 V	-
Emerson	142-0701-806	4	Digikey Order	Mouser Order	Newark Order	INA+, INB+, OUTA-, OUTB-	Conn Jack Rcpt End Launch Nickel	-
-	-	4	Digikey Order	Mouser Order	Newark Order	INA-, INB-, OUTA+, OUTB+	-	-
Sullins Connector Solutions	PBC36SAAN	4	Digikey Order	Mouser Order	Newark Order	J1, J5, J11, J13	Conn Header .100 SINGL STR 36POS	-
-	-	1	Digikey Order	Mouser Order	Newark Order	J12	-	-
TDK Corporation	VLS2012ET-6R8M	1	Digikey Order	Mouser Order	Newark Order	L1	Inductor Power 6.8 µH .64 A SMD	6.8 µH
C&K Components	SDA02H0SBD	1	Digikey Order	Mouser Order	Newark Order	MODE	Switch Dip Top Slide 2-POS SMD	-

Table 5. BOM (continued)

MANUFACTURER	PART NUMBER	QUANTITY	DIGIKEY PN	MOUSER PN	NEWARK PN	DESIGNATOR	DESCRIPTION	VALUE
Phoenix Contact	1759020	1	Digikey Order	Mouser Order	Newark Order	POWER	Term Block Hdr 3-POS R/A 5.08MM	-
Panasonic	ERJ-3EKF2000V	10	Digikey Order	Mouser Order	Newark Order	R1-R4, R16, R28, R38-R41	RES 200 Ω 1/10 W 1% 0603 SMD	200 Ω
Panasonic	ERJ-3EKF49R9V	14	Digikey Order	Mouser Order	Newark Order	R9-R15, R21-R27	RES 49.9 Ω 1/10 W 1% 0603 SMD	49.9 Ω
Panasonic	ERJ-3EKF3011V	1	Digikey Order	Mouser Order	Newark Order	R17	RES 3.01 kΩ 1/10 W 1% 0603 SMD	3.01 kΩ
Panasonic	ERJ-2RKF2002X	2	Digikey Order	Mouser Order	Newark Order	R18, R19	RES 20 kΩ 1/10 W 1% 0402 SMD	20 kΩ
-	-	8	Digikey Order	Mouser Order	Newark Order	R5-R8, R35, R36, R46, R48	-	-
Panasonic	ERJ-3EKF40R2V	4	Digikey Order	Mouser Order	Newark Order	R42-R45	RES 40.2 Ω 1/10 W 1% 0603 SMD	40.2 Ω
Panasonic	ERJ-2RKF2743X	1	Digikey Order	Mouser Order	Newark Order	R50	RES 274 kΩ 1/10 W 1% 0402 SMD	274 kΩ
Panasonic	ERJ-2RKF1003X	1	Digikey Order	Mouser Order	Newark Order	R51	RES 100 kΩ 1/10 W 1% 0402 SMD	100 kΩ
Panasonic	ERJ-6ENF3010V	4	Digikey Order	Mouser Order	Newark Order	R53-R56	RES 301 Ω 1/8 W 1% 0805 SMD	301 Ω
C&K Components	SDA08H1SBD	2	Digikey Order	Mouser Order	Newark Order	SWGA, SWGB	Switch Dip Top Slide 8-POS SMD	-
MINI-CIRCUITS	JTX-2-10T+	2	Mini-Circuits			T1, T2	Surface Mount RF Transformer 75 Ω 50 to 1000 mHz + RoHS compliant	-
MINI-CIRCUITS	TC4-1W+	2	Mini-Circuits			T3, T4	Surface Mount RF Transformer 50 Ω 3 to 800 mHz + RoHS compliant	-
Texas Instruments	LMH6521SQE/NOPB	1	Digikey Order	Mouser Order	Newark Order	U1	DUAL DVGA	-
Texas Instruments	LMR70503TM/NOPB	1	Digikey Order	Mouser Order	Newark Order	U2	IC Reg Buck BST INV ADJ 8DSBGA	-
Phoenix Contact	1757022	1	Digikey Order	Mouser Order	Newark Order	***SEE COMMENTS***	Conn Term Block Plug 2-POS 5.08 mm	-
Sullins Connector Solutions	SPC02SYAN	1	Digikey Order	Mouser Order	Newark Order	***SEE COMMENTS***	Conn Jumper Shorting Gold Flash	-

8 References

1. *LMH6521 High Performance Dual DVGA (Rev. D*) (LMH6521)

About the Author

LOREN SIEBERT Loren Siebert has been an applications engineer with National Semiconductor and Texas Instruments since 2000. Loren has supported high speed amplifiers in a wide array of applications ranging from video buffers to communications devices.

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