JFE150 Ultra-Low-Noise, Low-Gate-Current, Audio, N-Channel JFET

Texas Instruments
Burr-Brown Audio

1 Features

- Ultra-low noise:
  - Voltage noise:
    - 0.8 nV/√Hz at 1 kHz, I_{DS} = 5 mA
    - 0.9 nV/√Hz at 1 kHz, I_{DS} = 2 mA
  - Current noise: 1.8 fA/√Hz at 1 kHz
- Low gate current: 10 pA (max)
- Low input capacitance: 24 pF at V_{DS} = 5 V
- High gate-to-drain and gate-to-source breakdown voltage: –40 V
- High transconductance: 68 mS
- Packages: Small SC70 and SOT-23

2 Applications

- Microphone inputs
- Hydrophones and marine equipment
- DJ controllers, mixers, and other DJ equipment
- Professional audio mixer or control surface
- Guitar amplifier and other music instrument amplifier
- Condition monitoring sensor

3 Description

The JFE150 is a Burr-Brown™ discrete JFET built using Texas Instruments' modern, high-performance, analog bipolar process. The JFE150 features performance not previously available in older discrete JFET technologies. The JFE150 offers the maximum possible noise-to-power efficiency and flexibility, where the quiescent current can be set by the user and yields excellent noise performance for currents from 50 µA to 20 mA. When biased at 5 mA, the device yields 0.8 nV/√Hz of input-referred noise, giving ultra-low noise performance with extremely high input impedance (> 1 TΩ). The JFE150 also features integrated diodes connected to separate clamp nodes to provide protection without the addition of high-leakage, nonlinear, external diodes.

The JFE150 can withstand a high drain-to-source voltage of 40 V, as well as gate-to-source and gate-to-drain voltages down to –40 V. The temperature range is specified from –40°C to +125°C. The device is offered in 5-pin SOT-23 and SC70 packages.

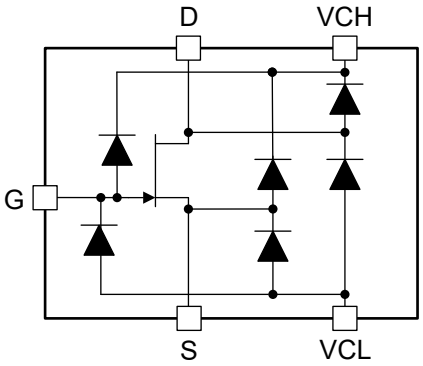
Package Information

PART NUMBER	PACKAGE(1)	BODY SIZE (NOM)
JFE150	DBV (SOT-23, 5)	2.90 mm × 1.60 mm
	DCK (SC70, 5)	2.00 mm × 1.25 mm

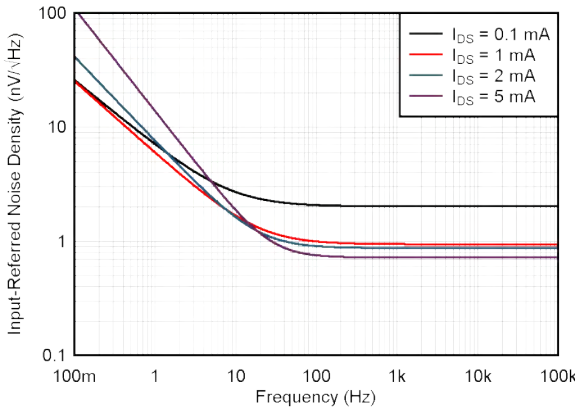
(1) For all available packages, see the package option addendum at the end of the data sheet.

Device Summary

PARAMETER		VALUE
V_{GSS}	Gate-to-source breakdown voltage	–40 V
V_{DSS}	Drain-to-source breakdown voltage	±40 V
C_{ISS}	Input capacitance	24 pF
T_J	Junction temperature	–40°C to +125°C
I_{DSS}	Drain-to-source saturation current	35 mA



Functional Block Diagram



Ultra-Low Input Voltage Noise

Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (November 2021) to Revision B (April 2023)	Page
• Changed DBV package (SOT-23, 5) from preview to production data (active) and added associated content.	1
• Changed parameter descriptions from "gate-to-source voltage" to "gate-to-source breakdown voltage" and from "drain-to-source voltage" to "drain-to-source breakdown voltage" in *Device Summary* table to match *Electrical Characteristics*	1
• Changed "drain-to-source saturation current" value from 36 mA to 35 mA in *Device Summary* table to match *Electrical Characteristics*	1
• Changed VCH and VCL pin type and description in *Pin Functions* to reflect optional nature of diode clamps	3
• Changed Figure 6-2, *Drain-to-Source Current vs Drain-to-Source Voltage,* to show correct V_{GS} values	6
• Changed Figure 8-1, V_{DS} *vs* I_{DS}, to show correct V_{GS} values and improve image resolution	10
• Added JFE150EVM user's guide and JFE150 Ultra-Low-Noise Pre-Amp application note to *Related Documentation*	18

Changes from Revision * (June 2021) to Revision A (November 2021)	Page
• Changed V_{GS} minimum from –1.1 V to –1.3 V (100 µA), –0.9 V to –1.1 V (2 mA)	5
• Changed Figure 6-3, *Drain-to-Source Current vs Drain-to-Source Voltage,* to show correct V_{GS} values	6

5 Pin Configuration and Functions

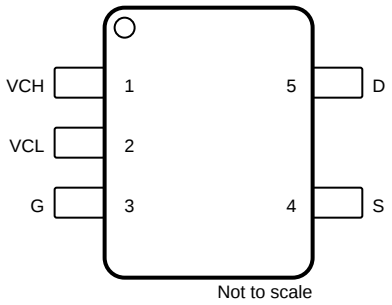


Figure 5-1. DBV, 5-Pin SOT-23 and DCK, 5-Pin SC70 Packages (Top View)

Table 5-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
D	5	Output	Drain
G	3	Input	Gate
S	4	Output	Source
VCH	1	—	Positive diode clamp voltage. Float this pin if clamp diodes are not used.
VCL	2	—	Negative diode clamp voltage. Float this pin if clamp diodes are not used.

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

			MIN	MAX	UNIT
V_{DS}	Drain-to-source voltage		–40	40	V
V_{GS}, V_{GD}	Gate-to-source, gate-to-drain voltage		–40	0.9	V
V_{VCH}	Voltage between VCH to D, G, or S			40	V
V_{VCL}	Voltage between VCL to D, G, or S		–40		
I_{VCL}, I_{VCH}	Clamp diode current	DC		20	mA
		50-ms pulse(2)		200	
I_{DS}	Drain-to-source current		–50	50	mA
I_{GS}, I_{GD}	Gate-to-source, gate-to-drain current		–20	20	mA
T_A	Ambient temperature		–55	150	°C
T_J	Junction temperature		–55	150	°C
T_{stg}	Storage temperature		–55	175	°C

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) Maximum diode current pulse specified for 50 ms at 1% duty cycle.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2500	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002((2))	±500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
I_{DS}	Drain-to-source current	0.02		I_{DSS}	mA
V_{GS}	Gate-to-source voltage	0		–1.2	V
T_A	Specified temperature	–40		125	°C

6.4 Thermal Information

THERMAL METRIC(1)		JFE150		UNIT
		DCK (SC70)	DBV (SOT-23)	
		5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	197.1	183.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	93.7	83.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	44.8	51.7	°C/W
ψ_{JT}	Junction-to-top characterization parameter	16.7	24.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	44.6	51.4	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics

at T_A = 25°C, I_{DS} = 2 mA, and V_{DS} = 10 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
NOISE							
e_n	Input-referred voltage noise density	I_{DS} = 100 µA , V_{DS} = 5 V	f = 10 Hz		3		nV/√Hz
			f = 1 kHz		2		
		I_{DS} = 2 mA, V_{DS} = 5 V	f = 10 Hz		1.6		
			f = 1 kHz		0.9		
		I_{DS} = 5 mA, V_{DS} = 5 V	f = 10 Hz		1.8		
			f = 1 kHz		0.8		
	Input-referred voltage noise	f = 0.1 Hz to 10 Hz, V_{DS} = 5 V	I_{DS} = 100 µA		0.19		μV_{PP}
			I_{DS} = 2 mA		0.09		
			I_{DS} = 5 mA		0.13		
e_i	Input current noise	f = 1 kHz, V_{DS} = 5 V			1.8		fA/√Hz
INPUT CURRENT							
I_G	Input gate current	V_{DS} = 2 V, V_{GS} = –0.7 V, V_{VCH} = 5 V, V_{VCL} = –5 V			0.2	±10	pA
		V_{DS} = 0 V, V_{GS} = –30 V			0.2		
			T_A = –40°C to +85°C			±2000	
			T_A = –40°C to +125°C			±10000	
INPUT VOLTAGE							
V_{GSS}	Gate-to-source breakdown voltage	V_{DS} = 0 V, $\|I_G\|$ < 100 µA				–40	V
V_{GSC}	Gate-to-source cutoff voltage	V_{DS} = 10 V, I_{DS} = 0.1 µA		–1.5	–1.2	–0.9	V
V_{GS}	Gate-to-source voltage	I_{DS} = 100 µA		–1.3		–0.7	V
		I_{DS} = 2 mA		–1.1		–0.5	
INPUT IMPEDANCE							
R_{IN}	Gate input resistance	V_{GS} = –5 V to 0 V, V_{DS} = 0 V			1		TΩ
C_{ISS}	Input capacitance	V_{DS} = 0 V			30		pF
		V_{DS} = 5 V			24		
C_{RSS}	Reverse transfer capacitance	V_{DS} = 0 V			7		
OUTPUT							
I_{DSS}	Drain-to-source saturation current	V_{DS} = 10 V, V_{GS} = 0 V		24	35	46	mA
			T_A = –40°C to +125°C	22		57	
gm	Transconductance	I_{DS} = 100 µA			3		mS
		I_{DS} = 2 mA			18		
G_{FS}	Full conduction transconductance	V_{DS} = 10 V, V_{GS} = 0 V		55	68	80	mS
V_{DSS}	Drain-to-source breakdown voltage	$\|I_{DS}\|$ < 100 µA, V_{GS} = –2 V		40			V
C_{OSS}	Output capacitance	V_{DS} = 5 V			8		pF

6.6 Typical Characteristics

at T_A = 25°C, I_{DS} = 2 mA, common-source configuration, and V_{DS} = 5 V (unless otherwise noted)

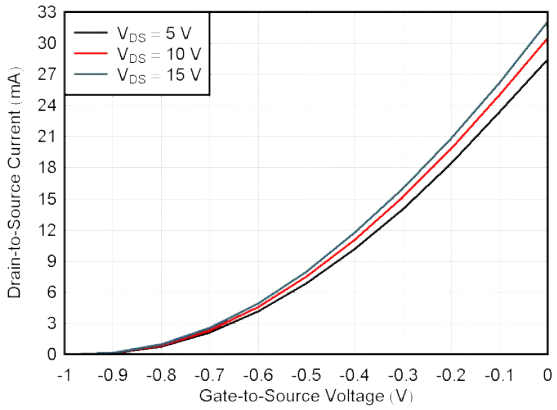


Figure 6-1. Drain-to-Source Current vs Gate-to-Source Voltage

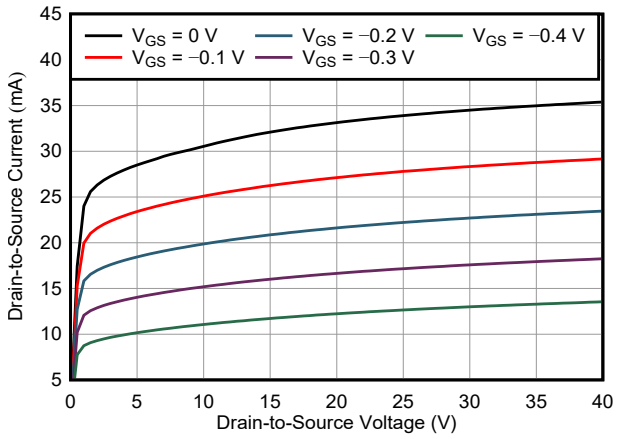


Figure 6-2. Drain-to-Source Current vs Drain-to-Source Voltage

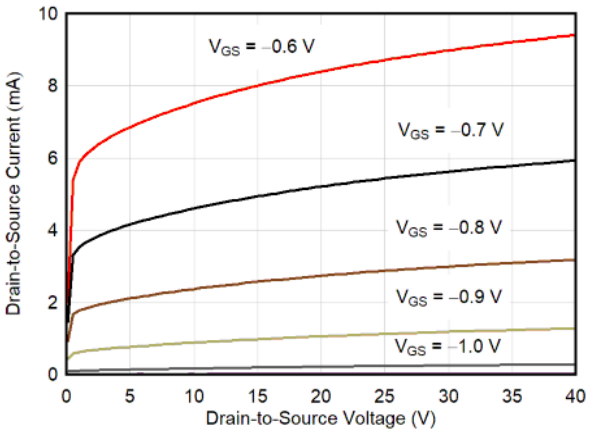


Figure 6-3. Drain-to-Source Current vs Drain-to-Source Voltage

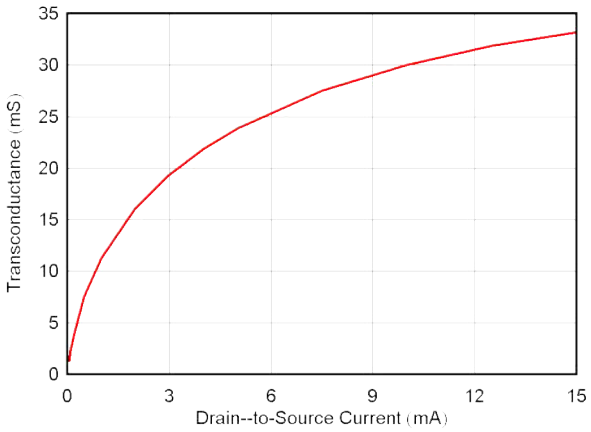


Figure 6-4. Common Source Transconductance vs Drain-to-Source Current

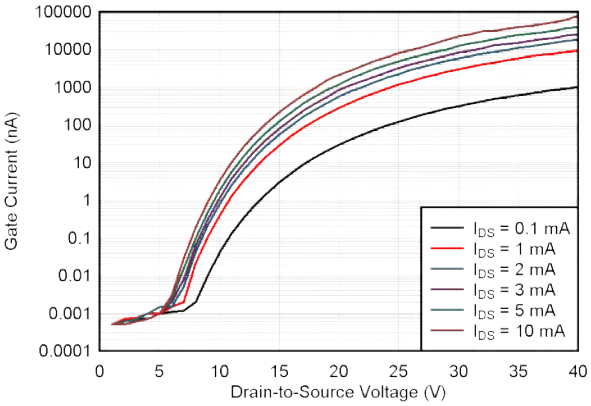


Figure 6-5. Gate Current vs Drain-to-Source Voltage

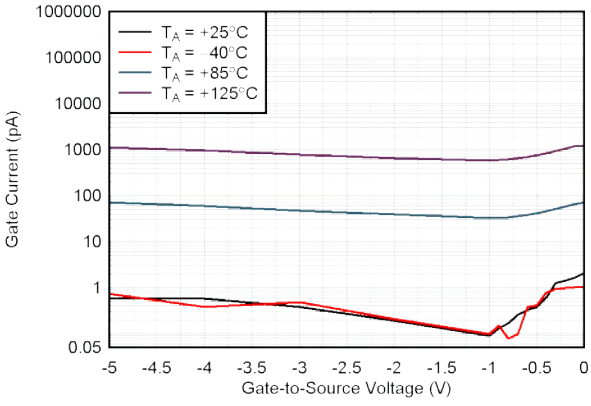
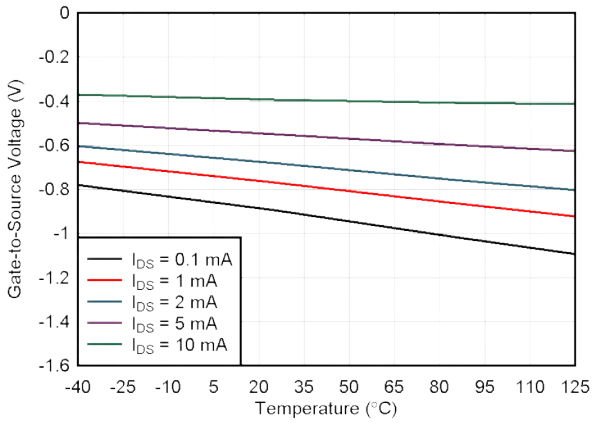


Figure 6-6. Gate Current vs Gate-to-Source Voltage

6.6 Typical Characteristics (continued)

at T_A = 25°C, I_{DS} = 2 mA, common-source configuration, and V_{DS} = 5 V (unless otherwise noted)



V_{DS} = 5 V

Figure 6-7. Gate-to-Source Voltage vs Temperature

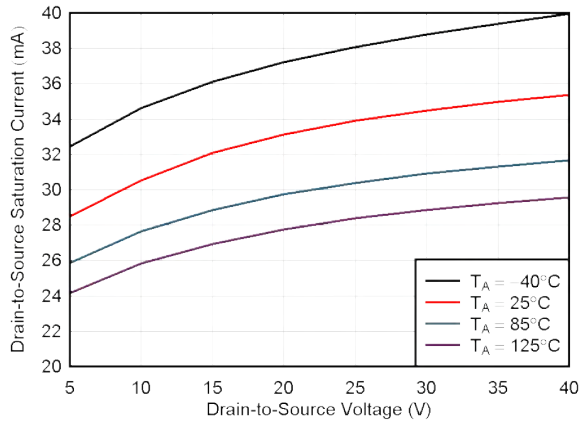


Figure 6-8. I_{DSS} vs Drain-to-Source Voltage

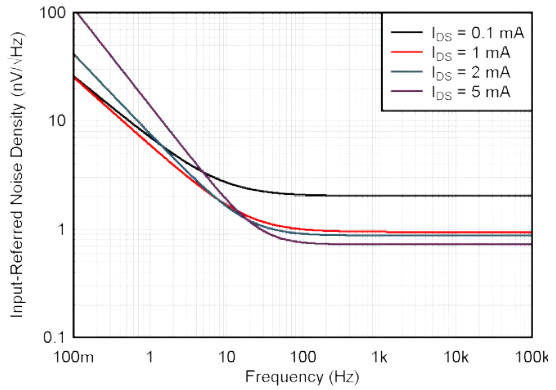
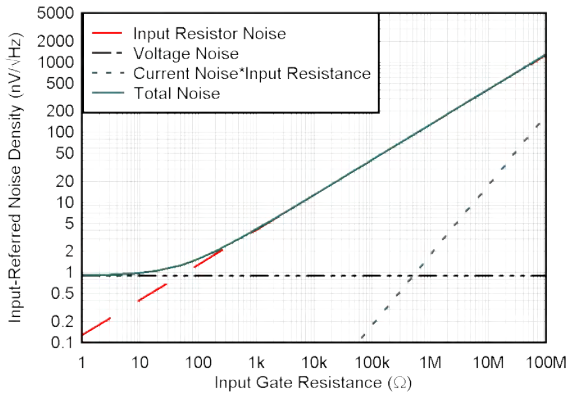
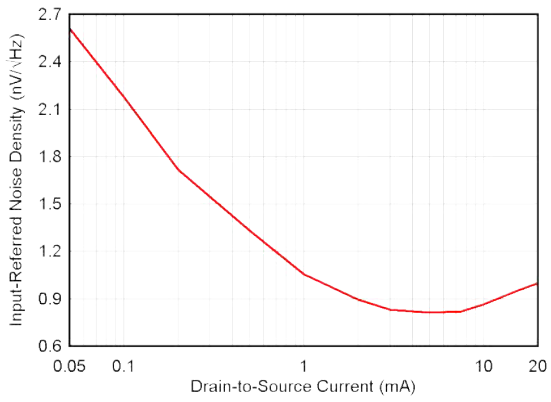


Figure 6-9. Input-Referred Noise Density vs Frequency



f = 1 kHz

Figure 6-10. Noise Density Contributors vs Input Gate Resistance



f = 1 kHz

Figure 6-11. Input-Referred Noise Spectral Density vs Drain-to-Source Current

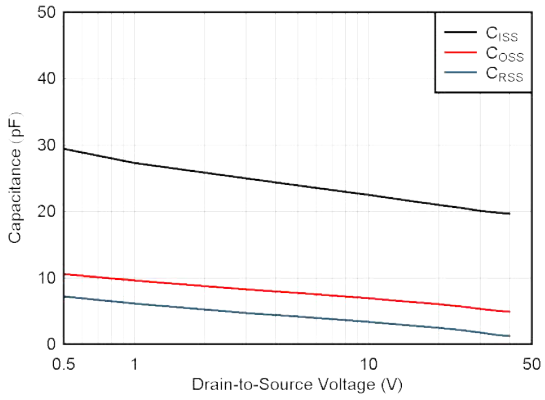


Figure 6-12. Input, Output, and Reverse Transfer Capacitance vs Drain-to-Source Voltage

7 Parameter Measurement Information

7.1 AC Measurement Configurations

The circuit configuration used for noise measurements is seen in Figure 7-1. The nominal I_{DS} current is configured in the schematic by calibrating V–. After I_{DS} is fixed, the V_{DS} voltage is set by calibrating V+. For input-referred noise data, the gain of the circuit is calibrated from V_{IN} to V_{OUT} and used for the input-referred gain calculation.

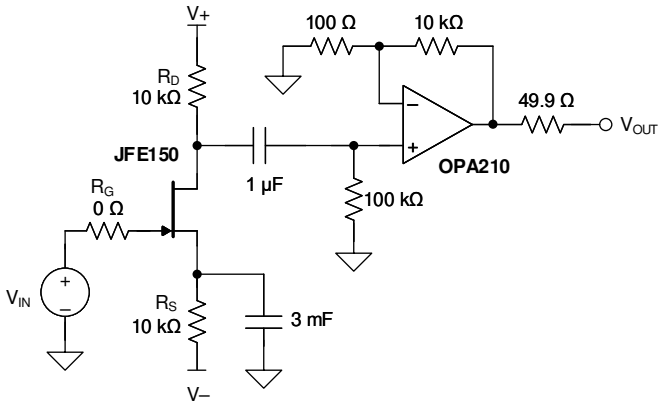


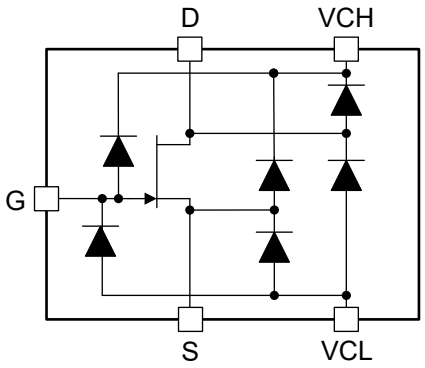
Figure 7-1. AC Measurement Reference Schematic

8 Detailed Description

8.1 Overview

The JFE150 is an ultra-low noise JFET designed to create low-noise gain stages for very high output impedance sensors or microphones. Advanced processing technology gives the JFE150 extremely low-noise performance, a high gm/C_{ISS} ratio, and ultra-low gate-current performance. Input protection diodes are integrated to clamp high-voltage spurious input signals without the need for additional input diodes that can add leakage current or distortion-creating non-linear capacitance. The JFE150 provides a next-generation device to implement low-noise amplifiers for piezoelectric sensors, transducers, large-area condenser microphones, and hydrophones in small-package options.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Ultra-Low Noise

Junction-gate field-effect transistors (JFETs) are commonly used as an input stage in high-input-impedance, low-noise designs in audio, SONAR, vibration analysis, and other technologies. The JFE150 is a new generation JFET device that offers very low noise performance at the lowest possible current consumption in high-input-impedance amplifier designs. The JFE150 is manufactured on a high-performance analog process technology, giving tighter process parameter control than a standard JFET.

Designs that feature operational amplifiers (op amps) as the primary gain stage are common, but these designs are not able to achieve the lowest possible noise as a result of the inherent challenges and tradeoffs required from a full operational amplifier design. Noise in JFET designs can be evaluated in two separate regions: low-frequency flicker noise and wideband thermal noise. Flicker, or 1/f noise, is extremely important for systems that require signal gain at frequencies less that 100 Hz. The JFE150 achieves extremely low 1/f noise in this range. Thermal noise is noise in the region greater than 1 kHz and depends on the gain, or gm, of the circuit. The gm is a function of the drain-to-source bias current; therefore, thermal noise is also a function of drain-to-source bias current. Figure 6-9 shows both 1/f and thermal noise with multiple bias conditions measured using the circuit shown in Figure 7-1.

Noise is typically modeled as a voltage source (voltage noise) and current source (current noise) on the input. The 1/f and thermal noise can be represented as voltage noise. Current noise is dominated by current flow into the gate, and is called *shot noise*. The JFE150 features extremely low gate current, and therefore, extremely low current noise. Figure 6-10 shows how source impedance on the input is the dominant noise source. In nearly all cases, noise created as a result of current noise is negligible.

8.3.2 Low Gate Current

The JFE150 features a maximum gate current of 10 pA at room temperature, making the device an excellent choice for maximizing the gain and dynamic range from extremely high impedance sensors. Additionally, any noise contributions as a result of gate current are minimized because of the negligible shot noise at low current levels. As with all JFET devices, when the drain-to-source voltage increases, the gate current also increases. Keep the drain-to-source voltage to less than 5 V for the lowest gate input current operation.

8.3.3 Input Protection

The JFE150 features input protection diodes that are used for surge clamping and ESD events. The diodes are rated to withstand high current surges for short times, steering current from the gate (G) pin to the VCH and VCL pins. The diodes also feature very low leakage, removing the need for external protection devices that can have high leakage currents or nonlinear capacitance that degrade the distortion performance.

8.4 Device Functional Modes

The JFE150 functionality is identical to standard N-channel depletion JFET devices. The gate-to-source (V_{GS}) voltage, drain-to-source voltage (V_{DS}) and drain-to-source current (I_{DS}) determine the region of operation.

- For $V_{GS} < V_{GSC}$: JFE150 conduction channel is closed; I_{DS} is only determined by junction leakage current.
- For $V_{GS} > V_{GSC}$: Two modes of operation can exist depending on V_{DS}. When V_{DS} is less than the linear (saturation) region threshold (see Figure 8-1), the device operates in the linear region, meaning that the device behaves as a resistor connected from drain-to-source with minimal variation from any changes in V_{GS}. When V_{DS} is greater than the linear (saturation) region threshold, I_{DS} has a strong dependance on V_{GS}, where the relationship is described by the parameter gm.

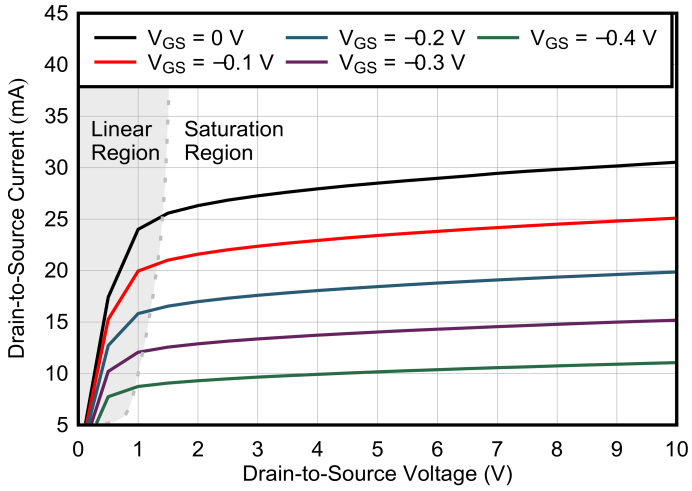


Figure 8-1. V_{DS} vs I_{DS}

9 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

9.1 Application Information

9.1.1 Input Protection Diodes

The JFE150 features diodes that are used to help clamp voltage surges that can occur on the input sensor to the gate. The diodes are connected between the gate and two separate pins, VCL and VCH. The clamping mechanism works by *steering* current from the gate into the VCL or VCH nodes when the voltage at the gate is less than VCL or greater than VCH. Figure 9-1 shows an example of a microphone input circuit where a dc blocking capacitor operates with a large dc voltage. When the microphone input is dropped or shorted, the dc blocking capacitor discharges into the VCL or VCH nodes, thus helping eliminate large signal transient voltages on the gate. There are also clamping diodes from the drain and source to VCL and VCH, respectively. The clamping diodes can withstand high surge currents up to 200 mA for 50 ms; however, limit dc current to less than 20 mA.

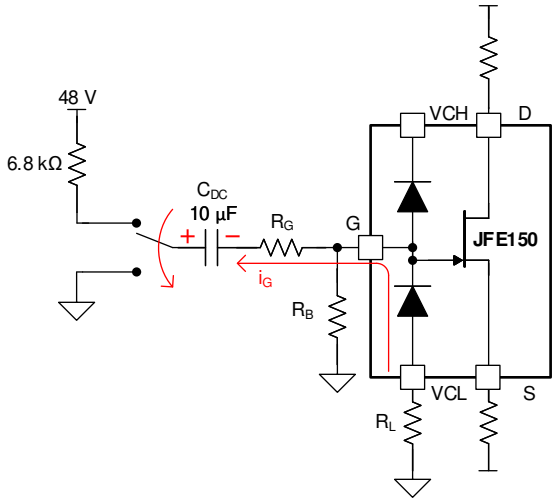


Figure 9-1. JFE150 Clamping Diode Example

Figure 9-1 shows an example of configuring the diode clamp to protect the JFET against overvoltage in a phantom-powered microphone circuit. Phantom power typically delivers 48 V through a 6.8-kΩ pullup resistor to a microphone or dynamic load. If the microphone is disconnected, dc blocking capacitor C_{DC} can be biased up to 48 V. If the input to the capacitor is then shorted to ground (shown by the switch in Figure 9-1), the gate voltage can exceed the absolute maximum rating for V_{GS}. In this case, the blocking diode is used, along with current limiting resistors R_G and R_L, to clamp the gate voltage to a safe level. Be aware that the thermal noise of R_G couples directly into the gate input; therefore, make sure to minimize the resistance of R_G.

The clamping diodes are not required for operation. The V_{GS} voltage can withstand –40 V, so clamping is not required if the V_{GS} voltage is kept greater than this limit. If the diodes are not needed, leave the VCL and VCH nodes floating.

Most previous-generation JFET devices featured only three pins (gate, source, and drain). For these devices, the gate pin is in the same physical location as the VCL pin on the JFE150. To test the JFE150 in a three-pin socket, short pin 2 of the JFE150 (VCL) to pin 3 (G). When the devices are connected with pin 2 shorted to pin 3, the diode from VCL is shorted out and cannot provide any clamping protection. The input capacitance (C_{ISS}) also increases by 1 pF; see Figure 6-12.

9.1.2 Capacitive Transducer Input Stage

Piezoelectric transducers are used for many different applications that require low-noise, high-gain performance. These transducers exhibit high output impedance (> 10 MΩ), and therefore require very high impedance loading for subsequent input stages. The JFE150 has ultra-low input gate current (maximum I_G = ±10 pA) and low input capacitance (C_{ISS} = 24 pF), which makes the device an excellent choice for transducers with an effective capacitance of greater than 240 pF. For smaller, lower-capacitance transducers, the C_{ISS} can impact the gain of the front end by attenuating the input signal, thereby reducing the noise performance.

9.1.3 Common-Source Amplifier

The common-source amplifier is a commonly used open-loop gain stage for JFET amplifiers. Figure 9-2 shows the basic circuit.

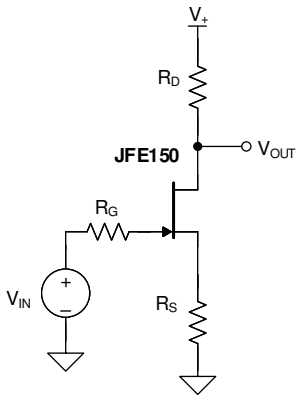


Figure 9-2. Common-Source Amplifier

Equation 1 shows the equation for gain of the circuit in Figure 9-2.

$$\frac{V_{OUT}}{V_{IN}} = -\frac{gm*R_D}{1+gm*R_S} \quad (1)$$

Generally, higher gain results in improved noise performance. Gain increases as the bias current is increased as a result of increasing gm (see Figure 6-4). As a result, the input-referred noise decreases as bias current is increased (see Figure 6-9). Any JFET design must make a tradeoff between current consumption and noise performance. The JFE150, however, delivers significantly lower noise performance than most operational amplifiers at the same current consumption. The bias current (I_{DS}) is set by the value of the source resistor, R_S, and the threshold voltage, V_T, of the JFE150. Figure 9-3 is a graph showing nominal I_{DS} vs R_S.

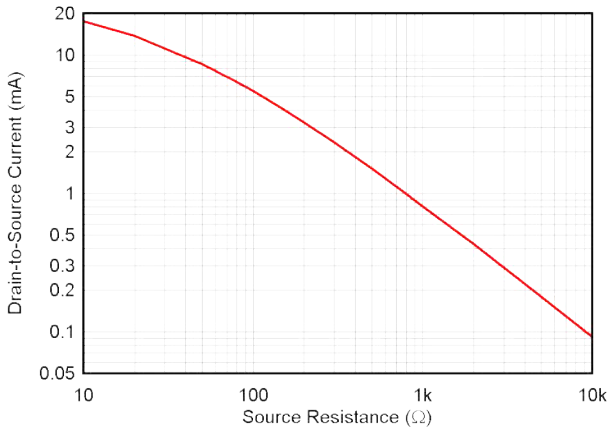


Figure 9-3. Drain-to-Source Current vs R_S, V_{DS} = 5 V

The bias current varies according to the resistor and threshold voltage tolerances. Additionally, thermal noise associated with R_S couples directly into the gain of the circuit, degrading the overall noise performance. To improve the circuit in Figure 9-4, use a current-source biasing scheme. Current-source biasing removes the JFET threshold variation from the biasing scheme, and allows for lower-value filtering capacitance (C_S) for equivalent filtering due to the high output impedance of current sources.

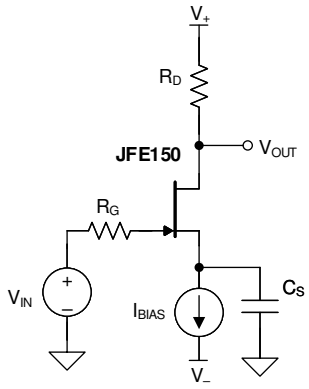


Figure 9-4. Common-Source Amplifier With Current-Source Biasing

9.1.4 Composite Amplifiers

The JFE150 can be configured to provide a low-noise, high-input impedance front-end stage for a typical op amp. Open-loop transistor gain stages shown previously suffer from wide gain variations that are dependent on the forward transcondutance of the JFE150. When precision gain is required, the composite amplifier (JFET front-end + operational amplifier) achieves excellent results by allowing for a fixed gain determined by external resistors, and improving the noise and bandwidth of the operational amplifier. The JFE150 gain stage provides a boost to the open-loop performance of the system, extending the bandwidth beyond what the operational amplifier alone can provide, and gives a high-input impedance, ultra-low noise input stage to interface with high source impedance microphones.

Figure 9-5 shows a generic schematic representation of a current-feedback composite amplifier. The component requirements and tradeoffs are listed in Table 9-1.

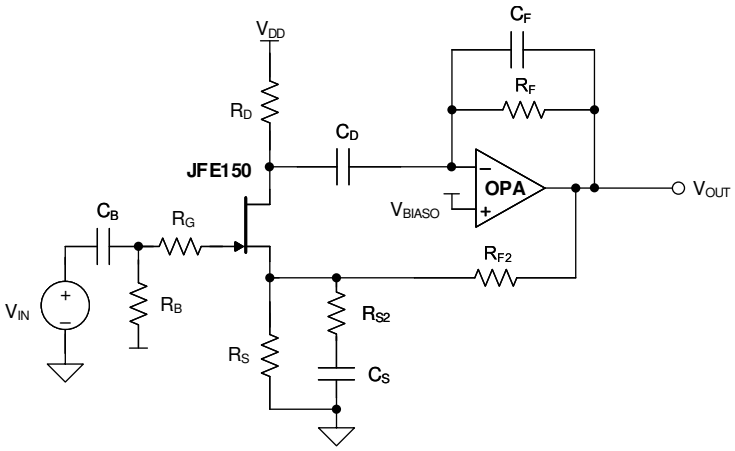


Figure 9-5. Low Noise, High Input Impedance Composite Amplifier

Table 9-1. Composite Amplifier Component List and Function

COMPONENT	DESCRIPTION	RELATED EQUATION
C_B	DC blocking capacitor for input source. Use a dc blocking capacitor if the dc voltage of the input source is not the same as the gate bias voltage.	$f_{-3dBDC} = \frac{1}{2*\pi*R_{B1}\|\|R_{B2}*C_{B1}}$ (2)
R_B	Bias resistor. Use biasing resistors to set the dc voltage at the gate. High-value resistors can be used without an impact to noise if the source impedance and bypass capacitor have sufficiently low impedance.	See Equation 2
R_G	Gate resistor. Can be used to help limit current flow into gate in overvoltage cases.	
R_D	Drain resistor. Sets gain of JFET stage in common source biasing, along with gm and R_S.	
R_S	Source resistor. Used to set bias of JFET; see Figure 9-3. Resistor thermal noise directly impacts noise performance.	
C_D	DC blocking capacitor. Blocks nominal drain voltage so the amplifier operates at a midsupply bias point.	
C_F	Feedback capacitor. Along with R_F, this capacitor sets the –3-dB high-pass cutoff frequency when the amplifier gain-bandwidth product (GBW) is sufficiently high enough to support the –3-dB frequency. If the GBW is not high enough, then the GBW sets the –3-dB frequency.	$f_{-3dBHP} = \frac{1}{2*\pi*R_F*C_F}$ (3)
R_F	Feedback resistor. Along with C_F, this resistor sets the –3-dB high-pass cutoff frequency when the amplifier gain-bandwidth product (GBW) is sufficiently high enough to support the –3-dB frequency. If the GBW is not high enough, then the GBW sets the –3-dB frequency.	See Equation 3
R_{F2}	Current feedback gain-setting resistor 1. Along with R_{S2}, sets gain closed-loop.	$\frac{V_{OUT}}{V_{IN}} = \frac{R_{F2}}{R_{S2}}$ (4)
R_{S2}	Current feedback gain-setting resistor 2. Along with R_{S2}, sets gain closed-loop. Resistor thermal noise directly impacts noise performance.	See Equation 4
C_S	Current feedback ac-coupling capacitor. This capacitor, along with R_2, sets the low-pass –3-dB frequency.	$f_{-3dBLP} = \frac{1}{2*\pi*R_{S2}*C_S}$ (5)

9.2 Typical Application

The JFE150 can be configured to provide a low-noise, high-input-impedance front-end stage for a typical op amp. Single-transistor gain stages shown previously suffer from wide gain variations dependent on the forward transcondutance of the JFE150. When precision gain is required, the composite amplifier (JFET front-end + operational amplifier) achieves excellent results.

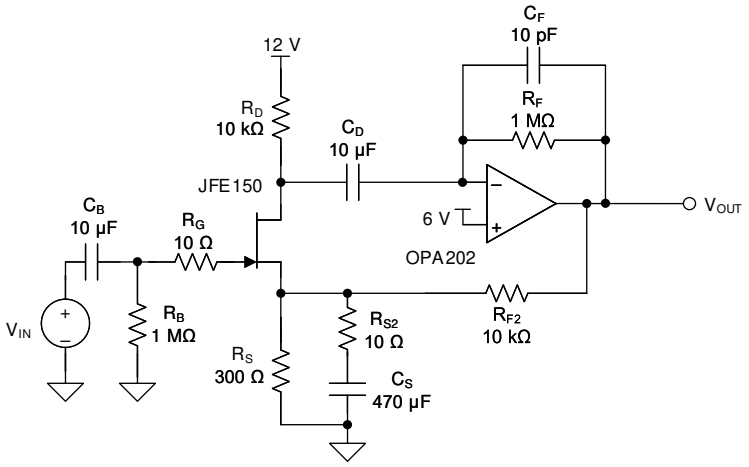


Figure 9-6. Low-Noise, High-Input-Impedance Composite Amplifier

9.2.1 Design Requirements

PARAMETER	DESIGN GOAL
Gain	60 dB
Frequency response	60 Hz to 20 kHz
Noise	< 1.5 nV/√Hz
Input current	< 100 pA
Output swing	±5 V

9.2.2 Detailed Design Procedure

This design provides 60 dB of gain with extremely high input impedance at a very low frequency response. The order of design priorities are as follows:

- The JFE150 bias current is set by selecting the desired bias current and noise tradeoff (see Figure 6-11). The input-referred noise is dominated by the JFE150 bias current and gain. To set the bias current point, adjust the source resistance according to Figure 9-3.
- After the bias current is selected, set the JFET stage gain as high as possible without pushing the device into the linear region of operation. This is achieved by using the largest drain resistor (R_D) possible while maintaining a minimum of 2 V across the drain to source nodes. Be aware that the amplifier forces the drain node to match the noninverting amplifier input in normal closed-loop operation. Both ac and dc voltages must be considered, but generally, only the dc operating point on the drain is considered because the ac voltage swing is minimal.
- Set the closed gain according to R_{F2} and R_{S2}, as seen in Equation 4. Thermal noise from R_{S2} directly couples into the circuit; therefore, small values for this resistor are required.
- C_S is required to block dc voltages from altering the bias point set by source resistor R_S. C_S also forms the low-frequency response as described in Equation 5.

9.2.3 Application Curves

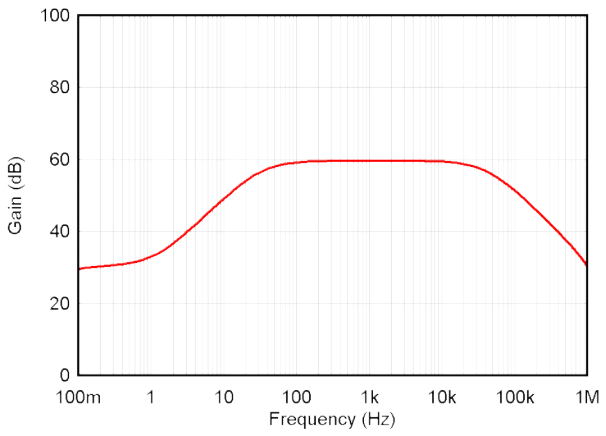


Figure 9-7. Voltage Gain

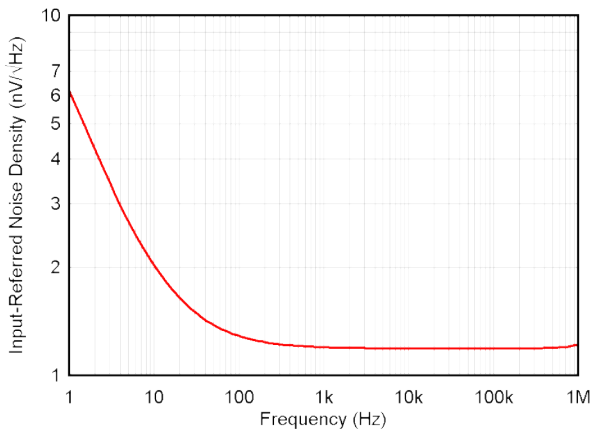


Figure 9-8. Input-Referred Noise Density

9.3 Power Supply Recommendations

The JFE150 is a JFET transistor with clamping diodes. There are no specific power-supply connections; however, take care not to exceed any absolute maximum voltages on any of the pins if system supply voltages greater than or equal to 40 V are used.

9.4 Layout

9.4.1 Layout Guidelines

For best operational performance of the device, use good printed-circuit board (PCB) layout practices, including:

- Reduce parasitic coupling by running the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Keep high impedance input signals away from noisy traces.
- Make sure supply voltages are adequately filtered.
- Minimize distance between source-connected and drain-connected components to the JFE150.
- Consider a driven, low-impedance guard ring around the critical gate traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- Clean the PCB following board assembly for best performance.
- Any precision integrated circuit can experience performance shifts resulting from moisture ingress into the plastic package. Following any aqueous PCB cleaning process, bake the PCB assembly to remove moisture introduced into the device packaging during the cleaning process. A low temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

9.4.2 Layout Example

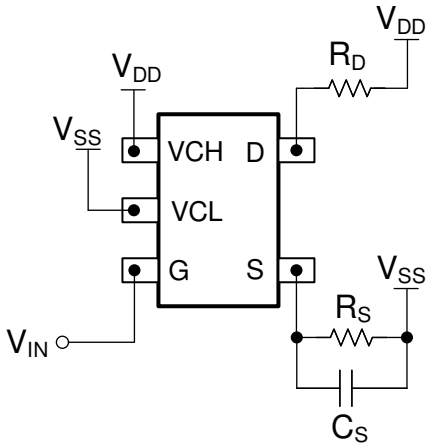


Figure 9-9. JFE150 Layout Example, Common Source Configuration

10 Device and Documentation Support

10.1 Device Support

10.1.1 Development Support

10.1.1.1 PSpice® for TI

PSpice® for TI is a design and simulation environment that helps evaluate performance of analog circuits. Create subsystem designs and prototype solutions before committing to layout and fabrication, reducing development cost and time to market.

10.1.1.2 TINA-TI™ Simulation Software (Free Download)

TINA-TI™ simulation software is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI simulation software is a free, fully-functional version of the TINA™ software, preloaded with a library of macromodels, in addition to a range of both passive and active models. TINA-TI simulation software provides all the conventional dc, transient, and frequency domain analysis of SPICE, as well as additional design capabilities.

Available as a free download from the Design tools and simulation web page, TINA-TI simulation software offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

Note

These files require that either the TINA software or TINA-TI software be installed. Download the free TINA-TI simulation software from the TINA-TI™ software folder.

10.1.1.3 TI Reference Designs

TI reference designs are analog solutions created by TI's precision analog applications experts. TI reference designs offer the theory of operation, component selection, simulation, complete PCB schematic and layout, bill of materials, and measured performance of many useful circuits. TI reference designs are available online at https://www.ti.com/reference-designs.

10.1.1.4 Filter Design Tool

The filter design tool is a simple, powerful, and easy-to-use active filter design program. The filter design tool allows the user to create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

Available as a web-based tool from the Design tools and simulation web page, the filter design tool allows the user to design, optimize, and simulate complete multistage active filter solutions within minutes.

10.2 Documentation Support

10.2.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *JFE150 Ultra-Low-Noise Pre-Amp* application note
- Texas Instruments, *JFE150 Evaluation Module* user's guide
- Texas Instruments, *OPAx202 Precision, Low-Noise, Heavy Capacitive Drive, 36-V Operational Amplifiers* data sheet
- Texas Instruments, *OPAx210 2.2-nV/√Hz Precision, Low-Power, 36-V Operational Amplifiers* data sheet

10.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

10.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

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PSpice® is a registered trademark of Cadence Design Systems, Inc.
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10.6 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

10.7 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
JFE150DBVR	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2GLW
JFE150DBVR.B	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2GLW
JFE150DBVT	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2GLW
JFE150DBVT.B	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2GLW
JFE150DCKR	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	1IF
JFE150DCKR.B	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	1IF
JFE150DCKT	Active	Production	SC70 (DCK) | 5	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	1IF
JFE150DCKT.B	Active	Production	SC70 (DCK) | 5	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	1IF

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

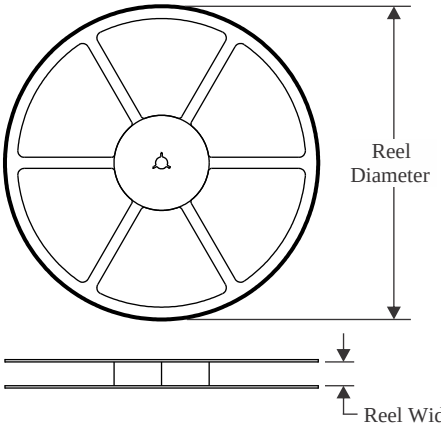
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

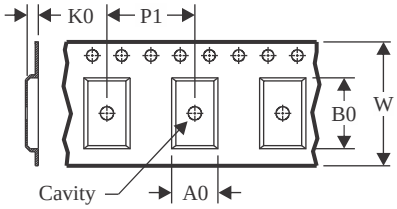
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

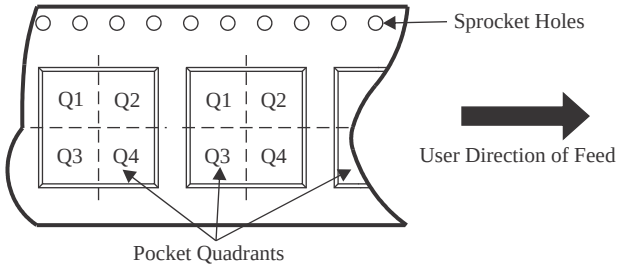


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

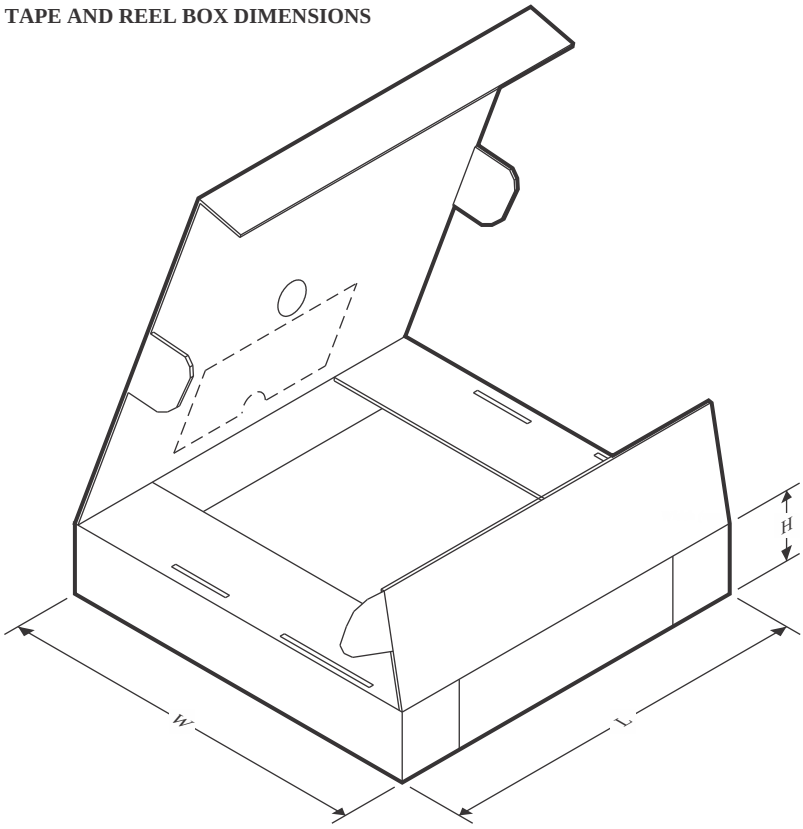
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
JFE150DBVR	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
JFE150DBVT	SOT-23	DBV	5	250	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
JFE150DCKR	SC70	DCK	5	3000	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3
JFE150DCKT	SC70	DCK	5	250	178.0	9.0	2.4	2.5	1.2	4.0	8.0	Q3
JFE150DCKT	SC70	DCK	5	250	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

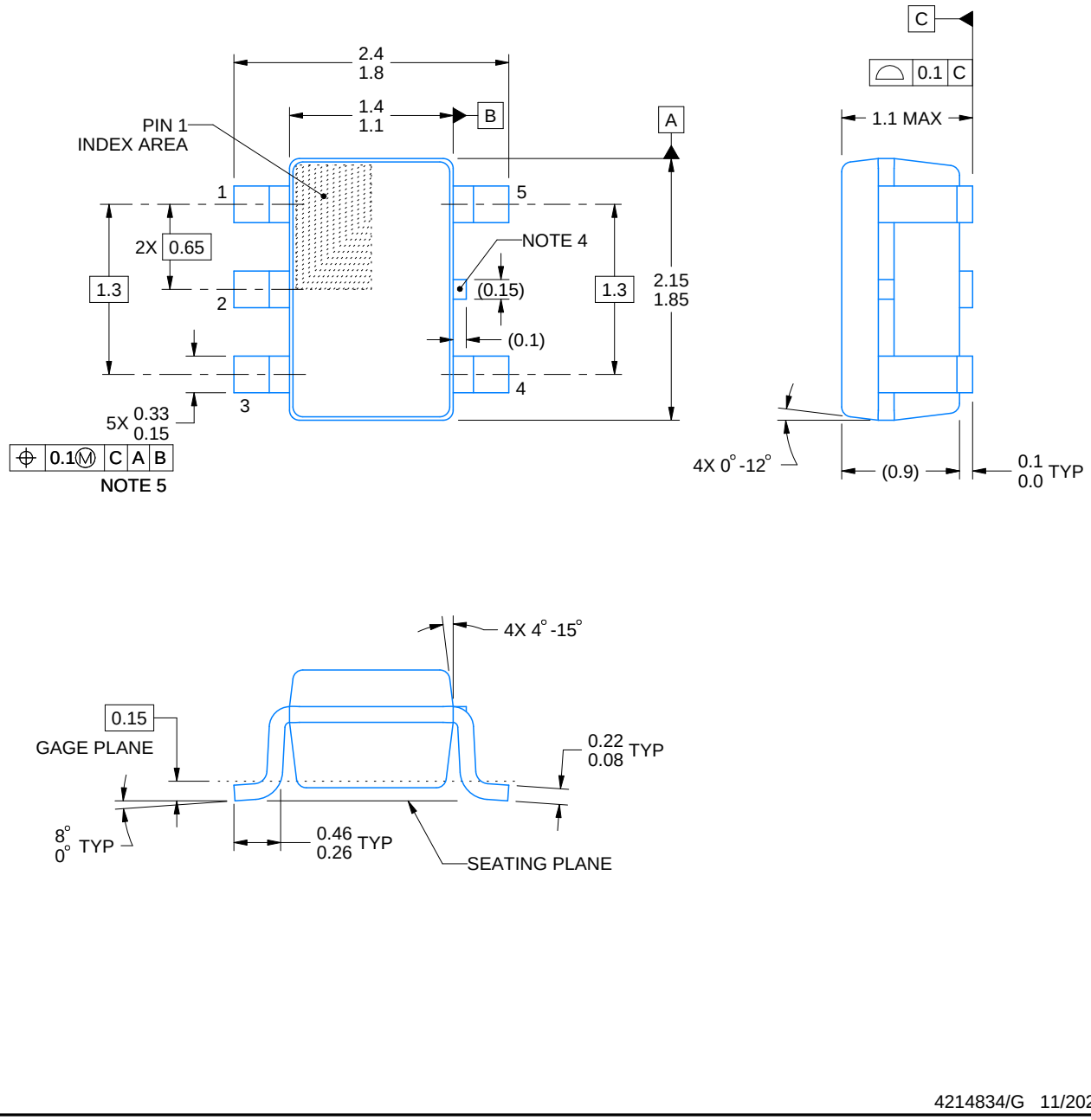
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
JFE150DBVR	SOT-23	DBV	5	3000	210.0	185.0	35.0
JFE150DBVT	SOT-23	DBV	5	250	210.0	185.0	35.0
JFE150DCKR	SC70	DCK	5	3000	210.0	185.0	35.0
JFE150DCKT	SC70	DCK	5	250	180.0	180.0	18.0
JFE150DCKT	SC70	DCK	5	250	210.0	185.0	35.0

PACKAGE OUTLINE

DCK0005A

SOT - 1.1 max height

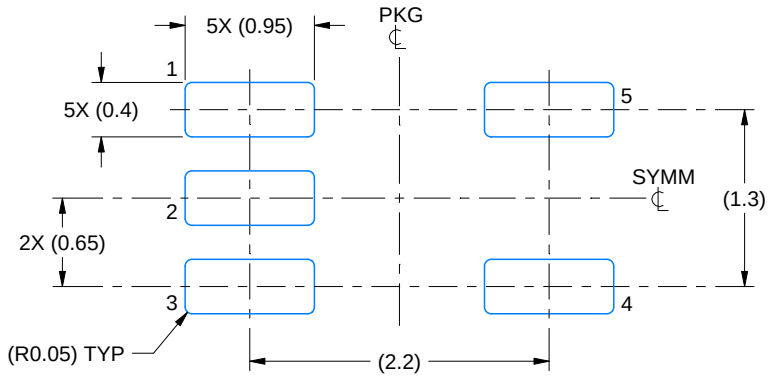
SMALL OUTLINE TRANSISTOR



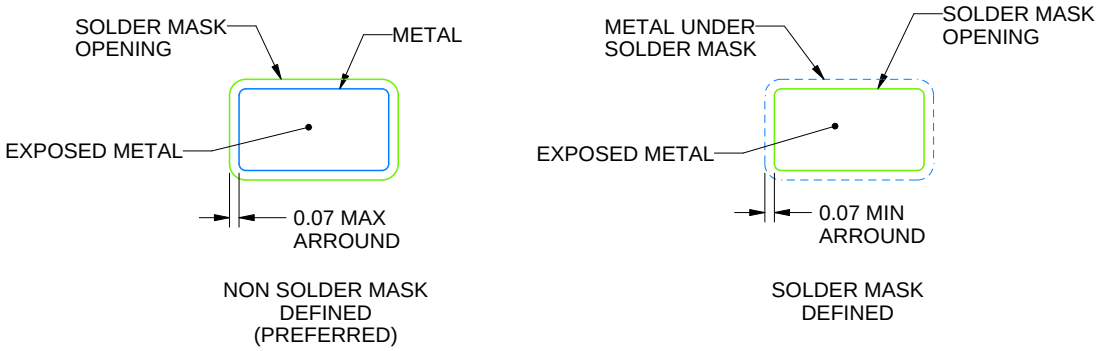
4214834/G 11/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X

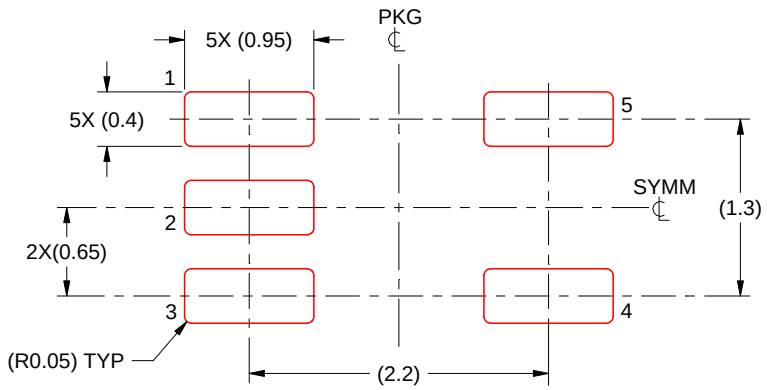


SOLDER MASK DETAILS

4214834/G 11/2024

NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.
8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:18X

4214834/G 11/2024

NOTES: (continued)

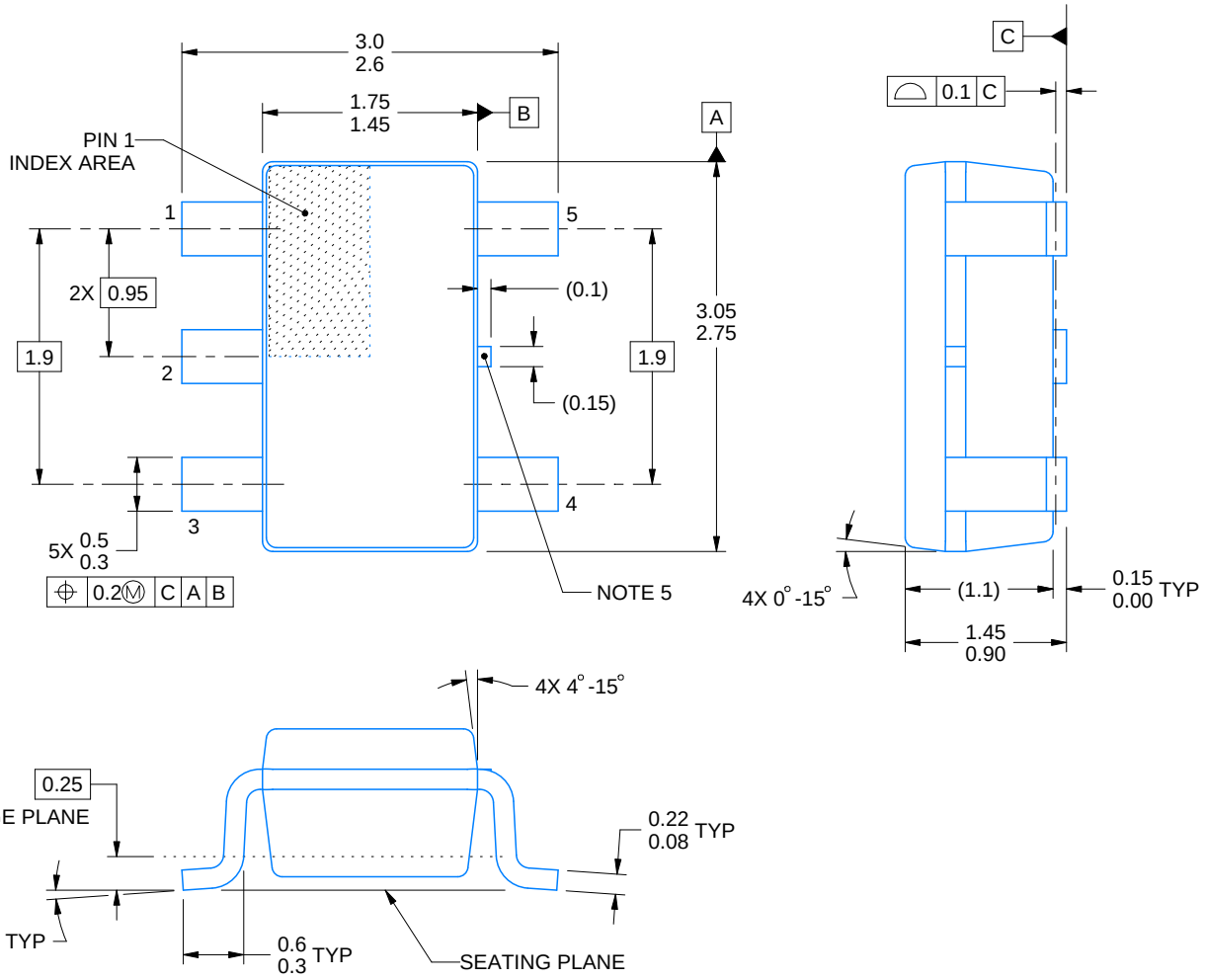
9. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
10. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

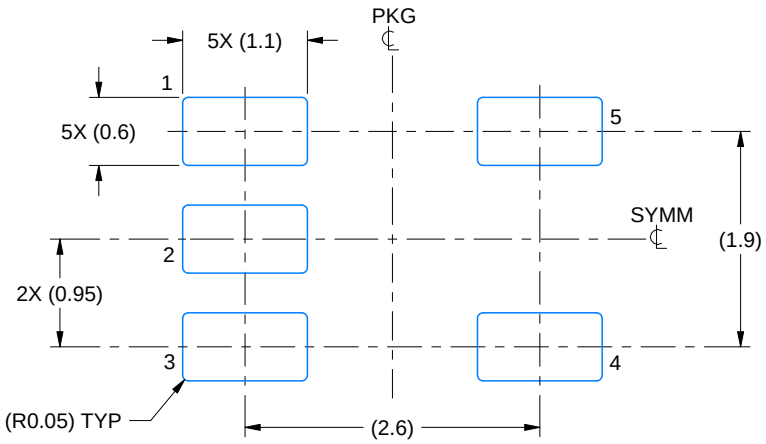
SMALL OUTLINE TRANSISTOR



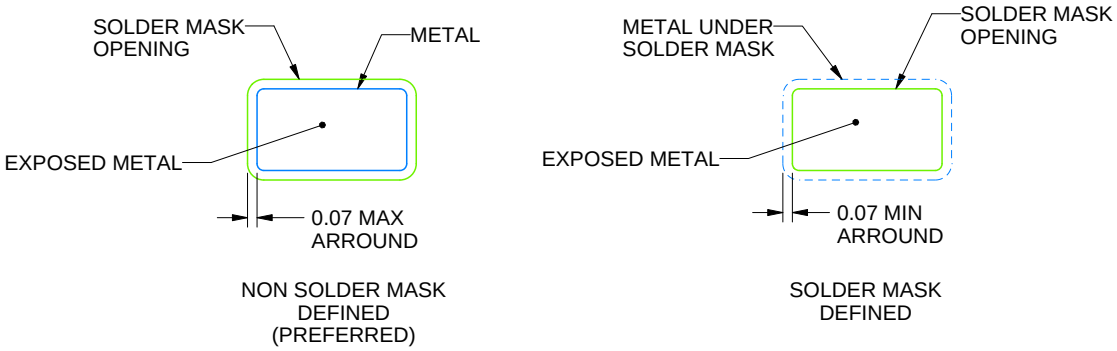
4214839/K 08/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

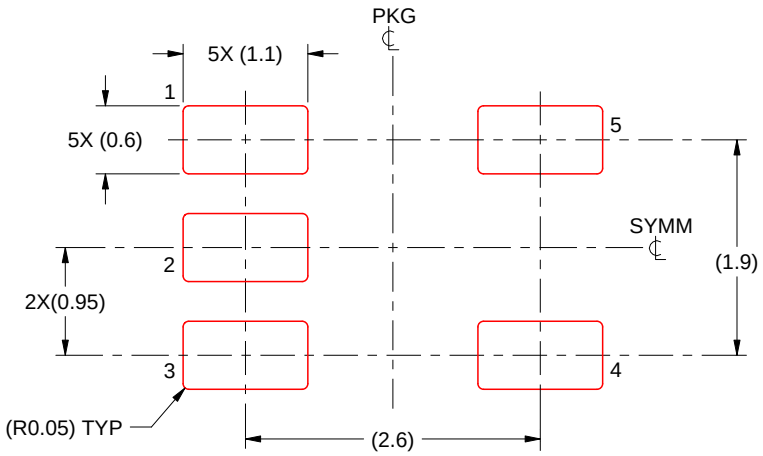


SOLDER MASK DETAILS

4214839/K 08/2024

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/K 08/2024

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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