TP5532 Evaluation Board User's Guide

Description

The TP5532 evaluation board contains a complete precision current sense amplifier using the TP5532 chopper amplifier in a high side, low side of floating supply current sense application.

The advantages of the TP5532 in this application include very low offset voltage (2μV typical) and offset drift (0.008μV/°C), rail-to-rail input and output and low power consumption (34μA per Amplifier typical). These features provide a very high degree of precision for use in 5V, low power applications.

Evaluation Board Key Features

The TP5532 EVB operates from a single 1.8VDC to +5.5VDC supply. The current sense function is configured as a single stage, balanced input, trans-impedance amplifier. A 0.1Ω 0.1% current sense resistor is used convert the incoming current to a voltage which is applied to a precision differential amplifier with a gain of 100. The overall current to voltage transfer ratio is 10V/A, and a bidirectional current range of ±0.25A is achieved when operating from a +5V supply, using a 2.5V reference voltage (V_{REF}). At +25°C, the TP5532 achieves a total full scale offset error of 0.038% (when a precision external reference is used) and approximately 0.15% using the internal 0.1% resistors. The total current draw from the amplifier power is less than 35μA and the total leakage current from the current sense input is less than 3μA.

Power Supply and Protection Features

External power connections are made through the +V, and ground jacks. The single supply input is overvoltage protected using a series 100Ω (R15) resistor and a 5.6V zener diode (D1). R15 is used to reduce the overvoltage from power supply, D1 is used to protect the chip from overvoltage, allows over current flows through it to ground. R15, C4 and C2 all works together as a RC low pass filter which filter the noise generated by power supply. Reverse polarity protection uses the 100Ω resistor and two protection diode pairs (D3, D4). These also provide input common mode voltage protection to the op amp.

Input Protection Clamp Options

Included on the evaluation board are optional input protection circuits that illustrate the best methods to limit input common mode and differential transient voltage spikes in exposed or electrically hazardous applications. The TP5532 can handle input common mode and differential transients to a diode drop beyond the rails, or to a range of -0.5V to +5.5V when operating from a single 5V supply. Clamp diodes D3A, B, D4A, B and input resistors R6, R7, R8, R9 form a current limiting, 6V common mode and differential voltage clamp. This clamp provides sufficient protection for the TP5532 for common mode fault voltages far beyond the power supply rails. These diodes also provide the same 6V protection against large differential transients. High speed current sensing may involve filtering repetitive current transients with high peak to average values. In these cases, limiting these transient even further will improve amplifier response and overload settling time. The optional Schottky diode transient clamp D2 reduces transients let through by the common mode clamp from 6V down to ~ ±0.3V, which improves overload recovery time. Capacitors C7 and C9 provide common mode noise filtering and capacitor C8 can be used to filter the current sense signal.

Current Sense Gain Equations

The current sense amplifier in Page 4 forms a trans-impedance amplifier whose gain is in units of V/A and is determined by the ratios of resistor pairs. R11:R8 and R14: R9. Resistor R11 is set equal to R14 and R8 is set equal to R9. This matching cancels the input offset voltage errors caused by the op amp input bias currents,

leaving behind only the offset voltage errors caused by the TP5532 input offset current (I_{OS}). The I_{SENSE} to V_{OUT} DC transfer function is given by Equation 1:

$$V_{OUT} = \left[I_{SENSE} \times R_{SENSE} \times \frac{R14}{R9}\right] + V_{REF} \quad \text{[EQ.1]}$$

where: R11 = R14 and R6 + R8 = R7 + R9

On the evaluation board, the R12, R9 resistor ratio is 100:1 (499kΩ: 4.9kΩ), and R_{SENSE} is 0.1Ω for a trans impedance gain given by Equation 2:

$$\frac{V_{SENSE}}{I_{SENSE}} = 10\ \frac{V}{A} \quad \text{[EQ.2]}$$

Input Range and Offset Error Analysis

The TP5532 output swings from rail-to-rail, and the evaluation board has a bi-directional output range of V_{REF} ±2.5V when operated from a +5V supply and V_{REF} is set to V_S/2. The evaluation board contains a jumper-selectable, internal V_S/2 reference or an external reference (V_{REF} pin). With V_{REF} set to +2.5, the full scale output range is 0 ±0.25A. The very low offset voltage (2μV +25°C max) and offset current (±100 pA +25°C max) of the TP5532 enable the use of very high values resistors for low current consumption while maintaining excellent precision in battery operated circuits. The total offset voltage contribution of the TP5532 is the sum of the input offset voltage (V_{OS}) and the offset voltage produced by the input offset current (I_{OS}) through the gain resistors and using the evaluation board resistor values and the data sheet maximum +25°C V_{OS} gives the total input offset voltage as shown in Equations 3, 4 and 5:

$$V_{OS(Total)} = \left(I_{OS} \times \left[\frac{R14 \times R9}{R14 + R9}\right]\right) + V_{OS} \quad \text{(EQ.3)}$$

$$V_{OS(Total)} = \left(3e-10 \times \left[\frac{R14 \times R9}{R14 + R9}\right]\right) + 8\mu V \quad \text{(EQ.4)}$$

$$V_{OS(Total)} = (3e-10 \times 4950) + 8\mu V = 9.5\mu V \quad \text{(EQ.5)}$$

Multiplying the TP5532 input offset voltage by the amplifier gain allows the input offset error to be expressed as a percent of full scale output voltage.

$$\%F.S.Error = \frac{V_{OS} \times \frac{R14}{R9}}{\pm 2.5V} = \pm 0.038\% \quad \text{(EQ.6)}$$

Using the Evaluation Board

The evaluation board has separate connections for the amplifier power supply, an output zero reference (V_{REF}), and the current sense terminals. The correct inter-connection between the I_{SENSE} terminals and the V_{REF} terminals are needed to implement the different types of current sense configurations.

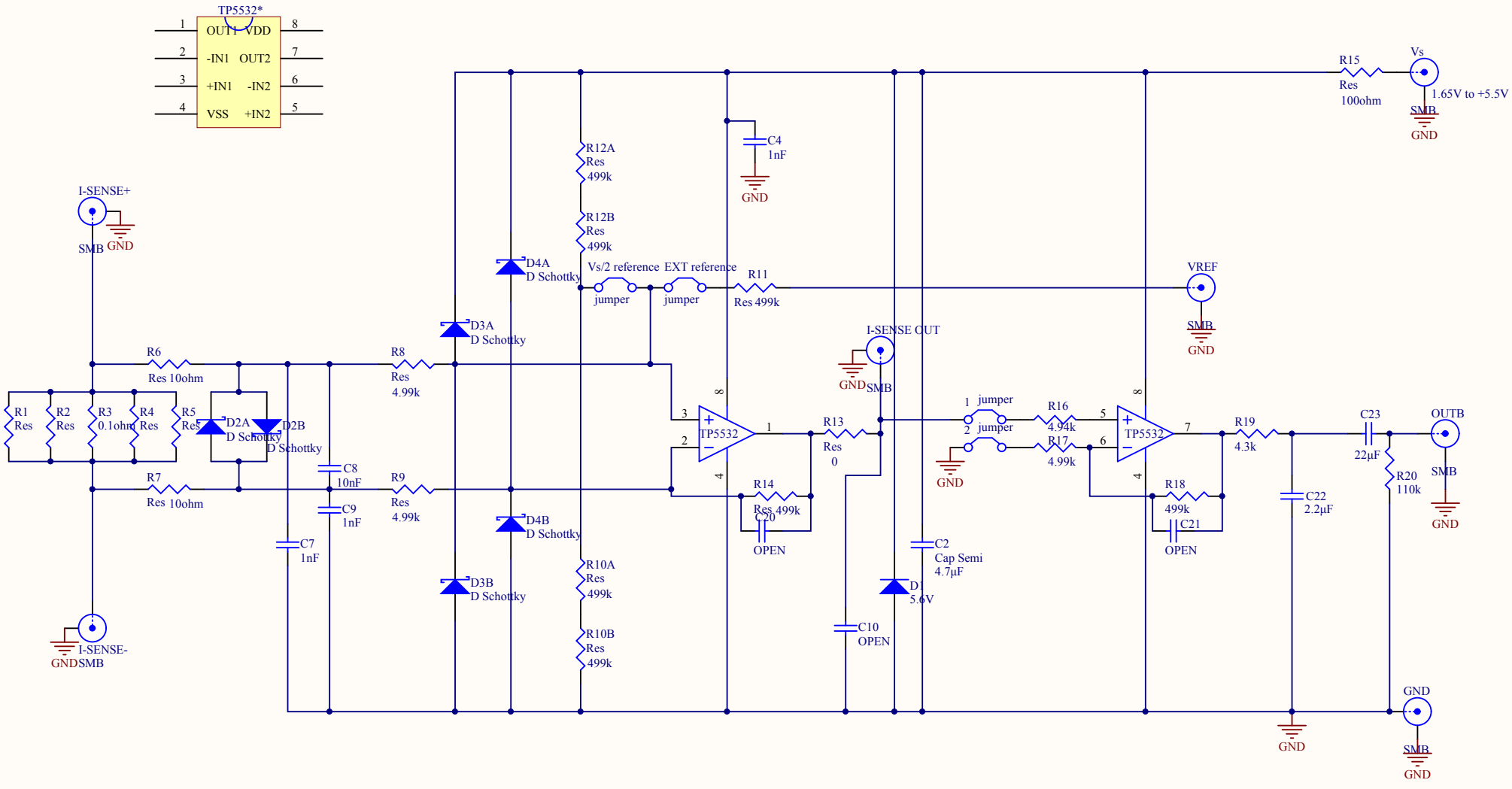
The I-SENSE+ and I-SENSE- connections to the measured circuit determine the polarity of the amplifier output voltage. Establishing a current flow from the I-SENSE + to I-SENSE - causes the output voltage to increase in proportion to the input current. Reversing the I-SENSE current flow reverses the output polarity.

The voltage applied to the V_{REF} pin defines the amplifier output zero current level, and must be between 0V and +5V. For bi-directional current sensing, a reference midway between the ground and the supply voltage will maximize the output span. For example, a V_{REF} = +2.5V would be the best choice for +5V power supply. The jumper selectable internal voltage divider is provided for this internal reference. The +2.5V will establish an output current scale setting 0A = +2.5V, but the accuracy is determined by the voltage divider accuracy (0.1% resistors on the evaluation board). Connecting the jumper to the external reference position enables an external reference source to be used. The TP5532 maintains precision performance from rail-to-rail making precision ground-side sensing possible.

Additional Feature

The TP5532 EVB can be also used for testing noise. The R18, R17 resistor ratio is 100:1 (499kΩ: 4.9kΩ), The evaluation board contains a jumper-selectable (jumper 1 and jumper 2) for choosing either inverting amplifier or non-inverting amplifier. Resistor R19 (4.3kΩ) and capacitor C22(2.2μF) work as a low pass filter which allows the signal frequency below 16.8Hz to pass.

Capacitor C23(22μF) and resistor R20(110KΩ) work as a high pass filter which allows the signal frequency above 0.1Hz to pass. The noise can be tested at the terminal OUTB.



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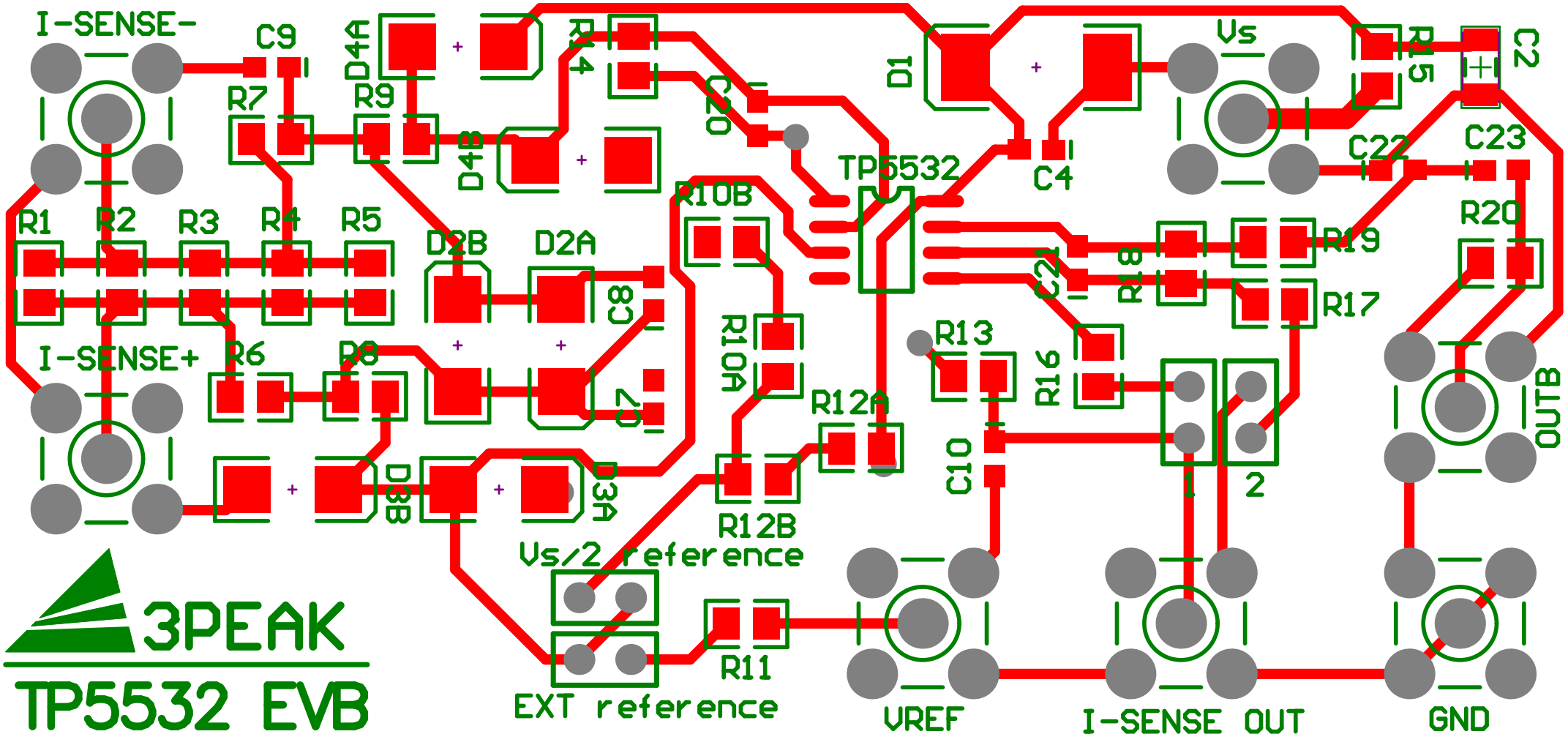
I-SENSE-
I-SENSE+
C9
R7
R9
D4A
D4B
R14
C20
D1
C4
Vs
R15
C2
C22
C23
TP5532
R10B
R10A
R1
R2
R3
R4
R5
D2B
D2A
C8
C7
R6
R8
R13
R16
C21
R18
R19
R17
R20
OUTB
C10
R12A
R12B
D3B
D3A
1
2
Vs/2 reference
R11
EXT reference
VREF
I-SENSE OUT
GND
3PEAK
TP5532 EVB

Comment	Description	Designator	Footprint	LibRef	Quantity
jumper		1, 2, EXT reference, Vs/2 reference	jumper	jumper	4
Cap Semi	Capacitor (Semiconductor SIM Model)	C2	CAPC3216L	Cap Semi	1
1nF		C4, C7, C9	0603	cap_0603	3
10nF		C8	0603	cap_0603	1
OPEN		C10, C20, C21	0603	cap_0603	3
2.2 μ F		C22	0603	cap_0603	1
22 μ F		C23	0603	cap_0603	1
5.6V	Default Diode	D1	DSO-C2/X3.3	Diode	1
D Schottky	Schottky Diode	D2A, D2B, D3A, D3B, D4A, D4B	DSO-C2/X2.3	D Schottky	6
SMB	SMB Straight Connector	GND, I-SENSE+, I-SENSE-, I-SENSE OUT, OUTB, VREF, Vs	SMB_V-RJ45	SMB	7
Res		R1, R2, R4, R5, R6, R7, R8, R9, R10A, R10B, R11, R12A, R12B, R13, R14,	0805	Res	16
0.1ohm		R3	0805	Res	1
4.94k		R16	0805	Res	1
4.99k		R17	0805	Res	1
499k		R18	0805	Res	1
4.3k		R19	0805	Res	1
110k		R20	0805	Res	1
		TP5532	SOP8	double opa	1
AD712		TP5532*	SOP8	AD712	1