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Parametric Measurement Unit and Supporting Components for ATE Applications Using the AD5522 PMU and the AD7685 16-Bit ADC

CIRCUIT FUNCTION AND BENEFITS

This circuit is a quad, parametric measurement unit (PMU) with supporting components to service a minimum of four device-under-test (DUT) channels. Typically, PMU channels are shared between a number of DUT channels. Although the AD5522 is very integrated and delivers four full PMU solutions, an external reference and an analog-to-digital converter (ADC) are required as a minimum to complete this portion of the automatic test equipment (ATE) signal chain. Typically, this reference and the ADC can be shared among multiple PMU packages. For further flexibility, additional external switches can be used to extend the capabilities of the PMU by extending the range of DUT capacitances that the AD5522 can drive.

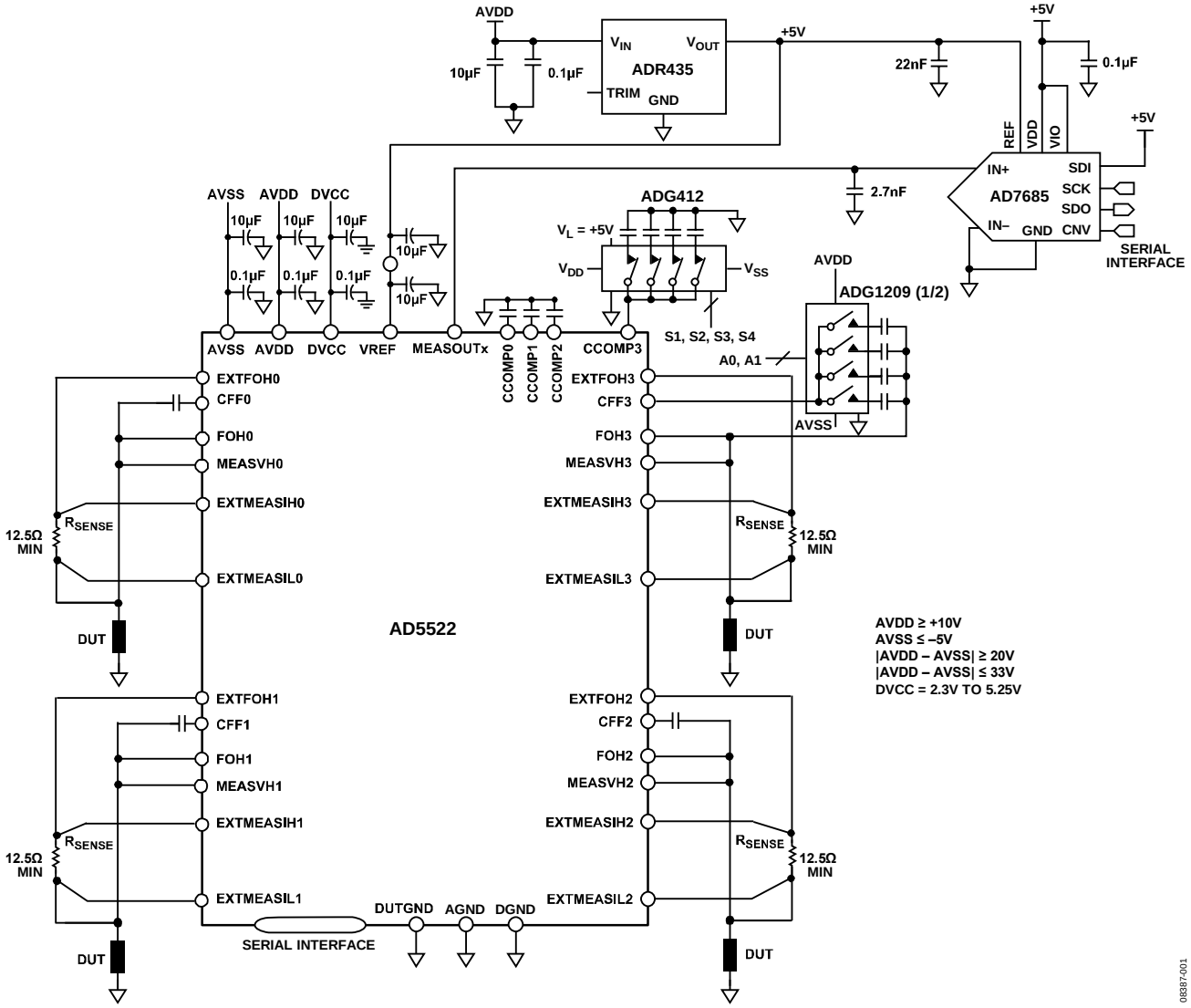

Figure 1. PMU and Supporting Components (Simplified Schematic)

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REVISION HISTORY

10/2018—Rev. 0 to Rev. A

Document Title Changed from CN-0104 to AN-1574 ..... Universal
Changes to Figure 1 1
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7/2009—Revision 0: Initial Version

CIRCUIT DESCRIPTION

The AD5522 quad PMU provides the forcing and measuring functions for the DUT. Digitizing is required external to the PMU, which can be achieved by doing one of the following:

- An ADC can be dedicated to each individual PMU channel, providing the fastest throughput and result.
- An ADC can be shared across multiple channels. In Figure 1, one AD7685 ADC is shared across the four PMU channels. In some applications, an ADC can be shared across many more channels, sometimes 8 or 16 PMU channels.

The ADC can be shared across channels using the internal disable feature of each MEASOUTx pin of the AD5522, which requires a write command to the PMU register to enable/disable the appropriate switches. If this method is chosen, select no more than one MEASOUTx channel at any one time.

Alternatively, an external 4:1 multiplexer can be used to control the measurement channel selection, which allows all four MEASOUTx paths to be enabled, and the multiplexer makes the selection. Similarly, an 8:1 or 16:1 multiplexer allows more measurement paths to share the one ADC. The choice of this multiplexer depends on the ADC used and its input voltage range. For bipolar input ADCs, the ADG1404 or ADG1204 is be ideal; for single-supply usage, the ADG706 or ADG708 is more suitable. The output impedance of the MEASOUTx path is typically 60 Ω in addition to the switch impedance. Consider an ADC buffer, such as the ADA4898-1 to drive the ADC (buffer not shown).

The AD7685 16-bit, 250 kSPS ADC was chosen for this application because of its ability to handle the 0 V to 4.5 V output range of the MEASOUTx path of the AD5522. In addition, the availability of other ADCs with faster speeds in the same footprint (for example, the 16-bit, 500 kSPS AD7686) also makes the AD7686 a good replacement candidate when high speed is required.

The AD5522 requires a 5 V reference if a 20 V output range is required. The ADR435 5 V XFET® reference was chosen because of its low tempco (10 ppm/°C, A Grade; 3 ppm/°C, B Grade), low noise (8 μV p-p, 0.1 Hz to 10 Hz), and ability to drive multiple PMU channels (30 mA output current source capacity, 20 mA output current sink capacity).

Some applications require the PMU to drive a wide range of DUT capacitances, especially applications where the PMU is connected to a power supply pin or where the PMU is used as a device power supply and sees the decoupling/bypass capacitance of the DUT. In such cases, an external switch connected to the CCOMPx pin, rather than a fixed capacitor, allows additional CCOMPx capacitors to be switched in and out, thereby allowing for optimization of settling time and stability with various capacitive loads. The switch chosen for this circuit was the ADG412 quad single-pole, single-throw (SPST) switch, which has an on-resistance (R_{ON}) of less than 35 Ω (typical). This quad SPST switch was chosen instead of a multiplexer because most multiplexers allow only one of a number of channels to be on at any one time. When using the quad switch, each of the drains can be connected together and the sources connected to the each of the compensation capacitors, which provides $2^4 - 1$ possible combinations of the CCOMPx channels.

Similarly, the ADG1209 differential multiplexer is used in this circuit to accommodate a wider range of feedforward capacitances connected to the CFFx pins of the AD5522, which enables the AD5522 to drive a wider range of DUT capacitance (C_{DUT}). Use the series resistance of the multiplexer such that $1/(2\pi \times R_{ON} \times C_{DUT}) > 100$ kHz. In this example, the ADG1209 services two AD5522 channels.

The switch and capacitors see the same voltage excursion as the voltage range at the FOHx pin of the AD5522. The voltage rating of the switch and capacitors must consider correlation. The CFFx capacitors can have a ≤10percentage tolerance. This extra variation directly affects settling times, especially in the measure current mode for low currents. Select the CCOMPx capacitors with ≤5percentage tolerance. Table 1 describes the various suggested values of load capacitance (C_{LOAD}) for nominal compensation capacitors CCOMPx and CFFx.

Table 1. Suggested Compensation Capacitor Selection

C_{LOAD}	CCOMPx	CFFx
≤1 nF	100 pF	220 pF
≤10 nF	100 pF	1 nF
≤100 nF	C_{LOAD}/100	C_{LOAD}/10

Note that in Figure 3 to Figure 6, FV refers to force voltage, FI refers to force current, MV refers to measure voltage, and MI refers to measure current. For details, refer to the AD5522 data sheet.

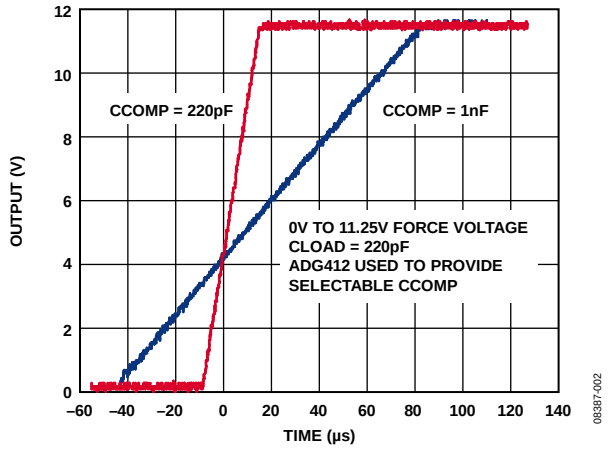

Figure 2. Output Voltage Step Response for 11.25 V Force Voltage Step with 220 pF Load for Various Values of CCOMPx Using the ADG412 SPST Switch

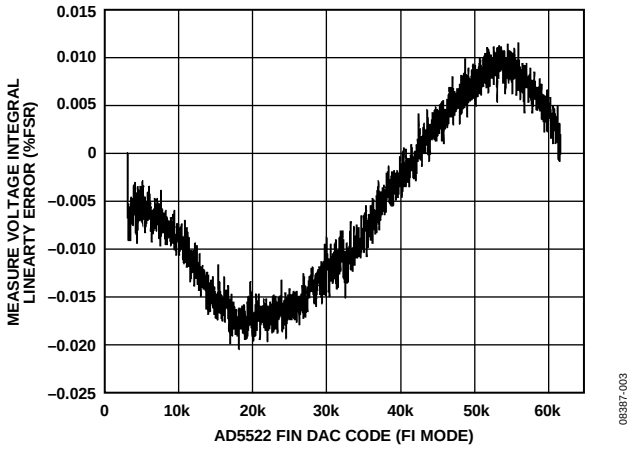

Figure 3. Integral Linearity Performance Using the AD7685 to Measure FIMV Error (FI Range = ±2 mA, MEASOUTx Gain = 0.2)

The circuit must be constructed on a multilayer printed circuit board (PCB) with a large area ground plane. Proper layout, grounding, and decoupling techniques must be used to achieve optimum performance (see Tutorial MT-031, *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND"* and Tutorial MT-101, *Decoupling Techniques*). Note that Figure 1 is a simplified schematic and does not show all of the necessary decoupling.

Careful consideration of the power supply and ground return layout helps to ensure the rated performance. Design the printed circuit board (PCB) on which the AD5522 is mounted so that the analog and digital sections are separated and confined to certain areas of the board. If the AD5522 is in a system where multiple devices require an AGND-to-DGND connection, make the connection at one point only. Establish the star ground point as close as possible to the AD5522.

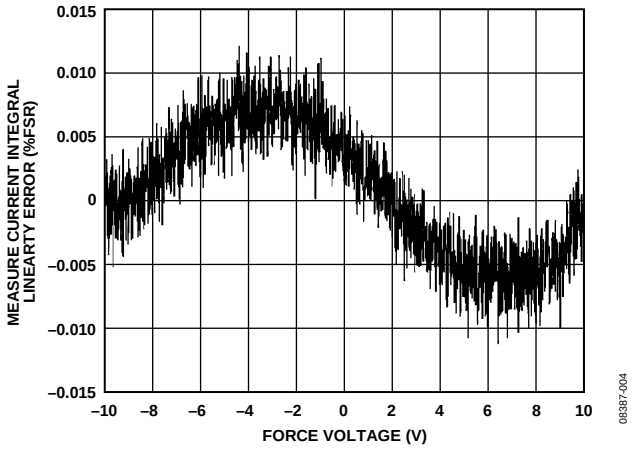

Figure 4. Integral Linearity Performance Using the AD7685 to Measure FVMI Error (FV Range = ±10 V in 2mA Range into a 5.6 kΩ Load)

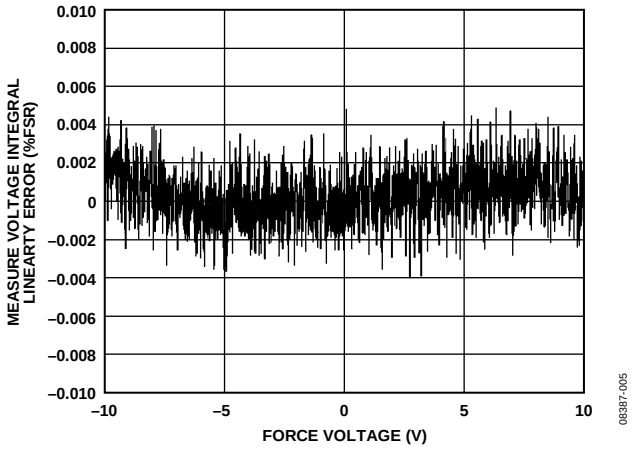

Figure 5. Integral Linearity Performance Using the AD7685 to Measure FVMV Error (FV Range = ±10 V, MEASOUTx Gain = 0.2)

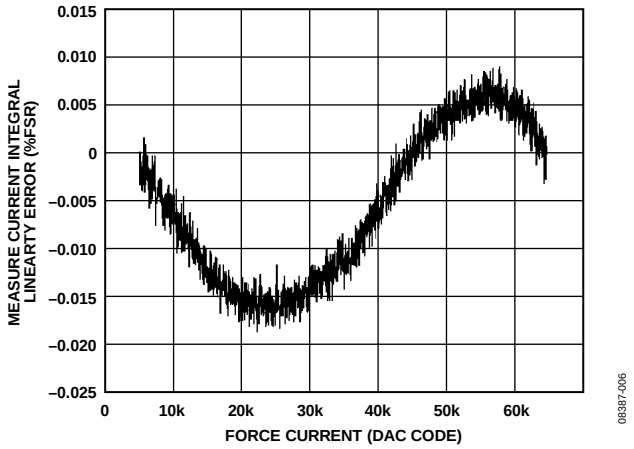

Figure 6. Integral Linearity Performance Using the AD7685 to Measure FIMI Error (FI Range = ±2 mA, MEASOUTx Gain = 0.2)

For supplies with multiple pins (AVSS and AVDD), it is recommended that these pins be tied together and that each supply be decoupled only one time.

The AD5522 must have an ample supply decoupling of 10 µF in parallel with 0.1 µF on each supply, located as close to the package as possible, ideally right up against the device. The 10 µF capacitors are the tantalum bead type. The 0.1 µF capacitors must have low effective series resistance (ESR) and low effective series inductance (ESL), which is typical of the common ceramic types that provide a low impedance path to ground at high frequencies, to handle transient currents due to internal logic switching.

Avoid running digital lines under the device because these lines can couple noise onto the device. Allow the analog ground plane to run under the AD5522 to avoid noise coupling (this applies only to the package with the exposed pad). The power supply lines of the AD5522 require as large a trace as possible to provide low impedance paths and reduce the effects of glitches on the power supply line. Shield fast switching digital signals with digital ground to avoid radiating noise to other areas of the board, and these signals must never be run near the reference inputs. It is essential to minimize noise on all VREF lines.

Avoid crossover of digital and analog signals. Run traces that are on opposite sides of the board at right angles to each other to reduce the effects of feedthrough through the board. As is the case for all thin packages, care must be taken to avoid flexing the package and to avoid a point load on the surface of the package during the assembly process.

Note that the exposed pad of the AD5522 is connected to the negative supply, AVSS.

COMMON VARIATIONS

PMU circuits do not always require the full 20 V output range of the AD5522. Many applications require only a portion of that voltage. For example, the use of the ADR421 2.5 V voltage reference allows the user to achieve a nominal output voltage range of ±5.6 V, which can be further scaled to suit the DUT requirements by using the on-chip offset digital-to-analog converter (DAC). See the AD5522 data sheet for details. The system power of the circuit also provides the benefit of being able to use lower supply rails, which reduces the power dissipated in the AD5522. This power dissipation is especially helpful when operating at the full 80 mA current range per channel.

Variations in terms of the partitioning of PMU measurement channels per ADC channel can mean that one ADC channel is shared among more PMU channels (sometimes in 8:1 or 16:1 ratios). Alternatively, the on-chip MEASOUT disable feature or an analog multiplexer can be used for this function. Multiplexers add more series resistance to the measurement path. Buffering can be required prior to the ADC input.

Other variations include the use of ADCs, which handle bipolar signal ranges, or ADCs with faster sampling rates.

REFERENCE

Automatic Test Equipment (ATE).

MT-031 Tutorial, *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND"*. Analog Devices.

MT-101 Tutorial, *Decoupling Techniques*. Analog Devices.

Voltage Reference Wizard Design Tool.

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