



Using Modular Instruments to Reduce Cost

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Agenda

- Strategy overview
- Uncertainty analysis
- Standard combination
- Software
- Shipping
- Questions

Strategies

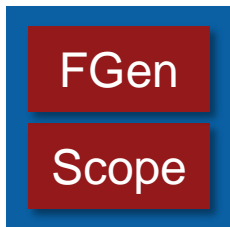
- Know your uncertainty
 - Know your standards
 - Know your DUTs
- Combine standards
- Use software to add functionality
- Save on shipping

Current Output Accuracy/Resolution*

Channel(s)	Range†	Resolution	Accuracy ± (% of output + offset)	
			1 Year 23 °C ± 10 °C	Tempco/ °C 0 °C to 55 °C
0	1 A	0.02 mA	0.15% + 4 mA	0.02% + 0.2 mA
1 and 2	20 mA	0.40 µA	0.15% + 60 µA	0.01% + 3 µA
	1 A	0.02 mA	0.15% + 4 mA	0.02% + 0.2 mA

Tempco = temperature coefficient
 * Calibrated at half of voltage range on channel. Applies to current limits greater than 2% of range. Applies to output current up to 500 mA. For output current greater than 500 mA, refer to the derating information in Figure 1.
 † Minimum programmable current limit is 2% of range.

TDR



```

j=1;
for (i=1;i<n;i+=2) {
    if (j > i) {
        SWAP(data[j],data[i]);
        SWAP(data[j+1],data[i+1]);
    }
    m=nn;
    while (m >= 2 && j > m) {
        j -= m;
        m >>= 1;
    }
    j += m;
}
    
```



Uncertainty Case Study – NI-4110 SMU

SMU Range	SMU Test Point (mA)	Required accuracy (mA)	M9182A accuracy (mA) / ratio	4070 accuracy (mA) / ratio	4071 accuracy (mA) / ratio
20 mA	0.00	0.012	0.00056 21x	0.003 4.0x	0.000009 1300x
20 mA	5.00	0.020	0.00285 7.0x	0.005 4.0x	0.00075 27x
20 mA	10.0	0.027	0.00510 5.3x	0.007 3.9x	0.0013 21x
20 mA	15.0	0.035	0.00735 4.8x	0.009 3.9x	0.0045 7.8x
20 mA	20.0	0.042	0.00960 4.4x	0.011 3.8x	0.0053 7.9x

Agilent M9182A 6.5 digit PXI DMM - \$1509

National Instruments PXI-4070 6.5 digit PXI DMM - \$2059

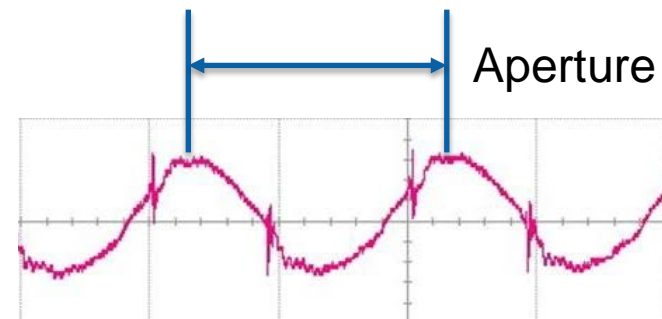
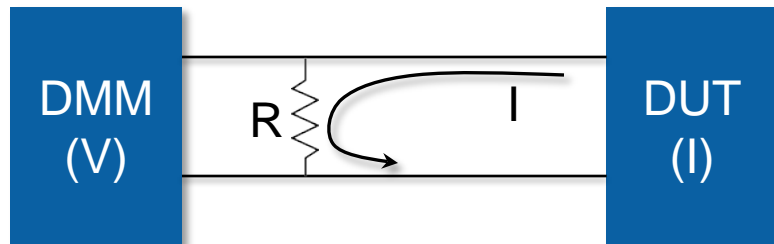
National Instruments PXI-4071 7.5 digit PXI DMM - \$3119

NI-4110 Case Study – continued

SMU Range	SMU Test Point (mA)	Required accuracy (mA)	M9182A accuracy (mA) / ratio	4070 accuracy (mA) / ratio	4071 accuracy (mA) / ratio
1 A	0.00	2.00	0.00056 3571x	0.003 667x	0.000009 22222x
1 A	250	2.05	0.600 3.4x	0.175 12x	0.0080 256x
1 A	500	2.50	1.100 2.2x	0.300 8.3x	0.140 18x
1 A	750	4.00	1.600 2.5x	0.425 9.4x	0.200 20x
1 A	1000	5.50	2.100 2.6x	0.550 10x	0.260 21x

Combine Standards – Higher Accuracy

- Use inexpensive higher accuracy standard to compensate for inexpensive lower accuracy standard
 - DMM and resistor for low current measurements
 - DMM and high voltage power supply for accurate high voltage
- Use aperture time to advantage
- Synchronize measurement for added accuracy



DMM + Shunt Resistor

SMU Range	SMU Test Point (mA)	Required accuracy (mA)	4070 + 1°C (mA) / ratio	4070 + onsite Ω cal (mA) / ratio	4071 accuracy (mA) / ratio
20 mA	0.00	0.012	0.000008 1500x	0.000008 1500x	0.000009 1300x
20 mA	5.00	0.020	0.00059 34x	0.0013 15x	0.00075 27x
20 mA	10.0	0.027	0.00095 28x	0.0023 12x	0.0013 21x
20 mA	15.0	0.035	0.0013 27x	0.0034 10x	0.0045 7.8x
20 mA	20.0	0.042	0.0017 25x	0.0044 9.5x	0.0053 7.9x

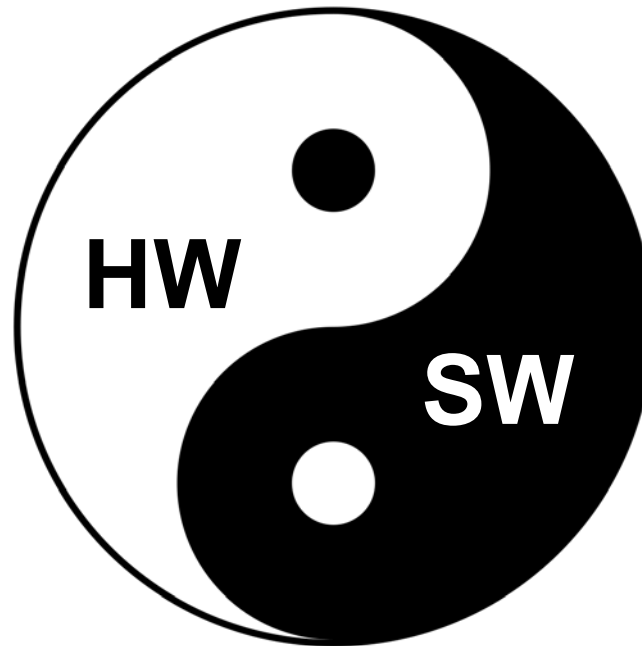
250Ω, 10W, 20ppm/°C shunt resistor (RCD 175-2500-FBW)
 Columns assume offsite cal and 1°C temperature change of resistor
 or onsite cal of resistor using the 4070

Combine Standards – New Functionality

- Source + Sink – loopback tests
 - Oscilloscope and function generator – time domain reflectometer
 - RF signal analyzer and RF signal generator – vector network analyzer
- Add Signal Conditioner
 - Add ranges
 - Add measurement modes
 - Current mode to voltage input device
 - Strain gauge support
 - Digitizer to DIO

Software

- Modular instruments are primarily software based
- Software can add functionality
 - Power spectrum from oscilloscope
 - RF power from RF vector signal analyzer





Abstraction Layers

- Common interface
- Used at any level
- Reduce coupling between standards and procedures



FPGAs Are Coming...

- Software defined instrument
- Custom triggering
- Custom data analysis
- Calibration automation

Shipping

- Modular instruments are much smaller and lighter than traditional instruments
- Modular instruments have more targeted functionality than a calibrator
- Combining instruments gains broad functionality



Traditional
Overnight
\$1378

NI PXIe-5644R Calibration
Ship Austin, TX to Huntsville, AL

Modular
Overnight
\$95





Synopsis

- Check uncertainties
- Combine instruments
- Use software to enhance and create functionality
- Save on shipping

Questions

