

Automatic Test Equipment

ARROW FAE
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Agenda



ATE Introduce

ADI ATE Product Introduce

- Per Pin Parametric Measurement Unit(PPMU)
- Device Power Supply(DPS)
- Switch & Multiplexer

ADI High Speed Test Solution

- MEMS Switch
- Digital Tunable Filters

ADI Power Solution

uModule

Do you know them?



DPS?

PMU?

DCL?

PPMU?

FV/FI?



Teradyne ETS-364 System

Terminology



- DPS
 - Device Power Supply
- PPMU
 - Per Pin Parametric Measurement Unit
- DCL
 - Driver, Comparator and Load
- ► PE
 - Pin Electronic
- ► DUT
 - Device Under Test
- FV/FI (same as CV/CC)
- VCH / VCL

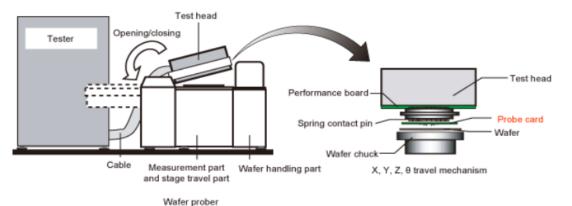
A probe card is a jig used for electrical testing of an LSI (large-scale integrated circuit) chip on a wafer during the wafer test process in LSI manufacturing.

A probe card is docked to a wafer prober to serve as a connector between the LSI chip electrodes and an LSI tester as a measuring machine. The needles of the probe card contact the LSI chip electrodes to conduct electrical testing for the go/no-go test.

The wafer test process is highly important and highly dependent on the reliability of probe cards.

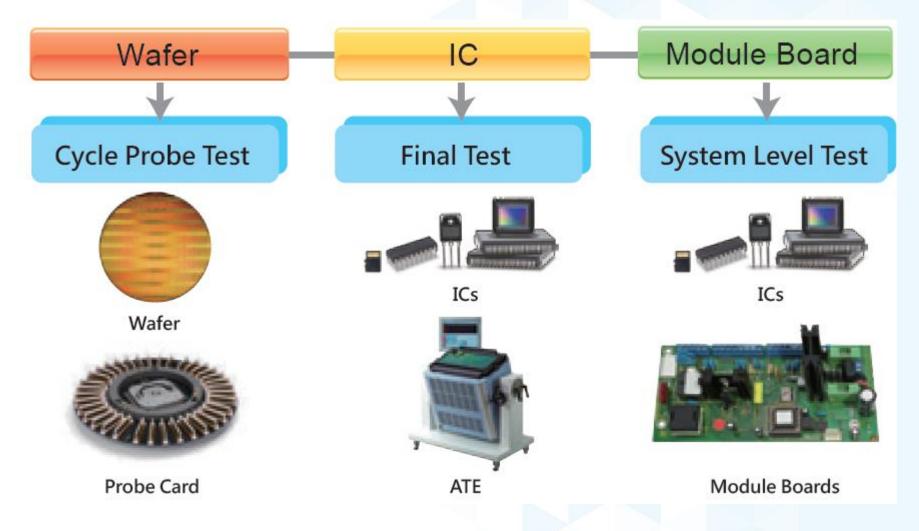
Probe Card Probe needle Mold base Printed circuit board Wafer Bonding pad LSI chip

Wafer Test System



IC Manufacture Test Process





Picture is refer to Chroma website

ATE Tester Category ---- DUT



Digital

- GPU
- CPU
- DSP
- Logic IC

- MIPI interface
- Video IC
- PCI
- High Speed Interface

Mix-signal

- Data converter
- IoT IC
- Power
- RF parts

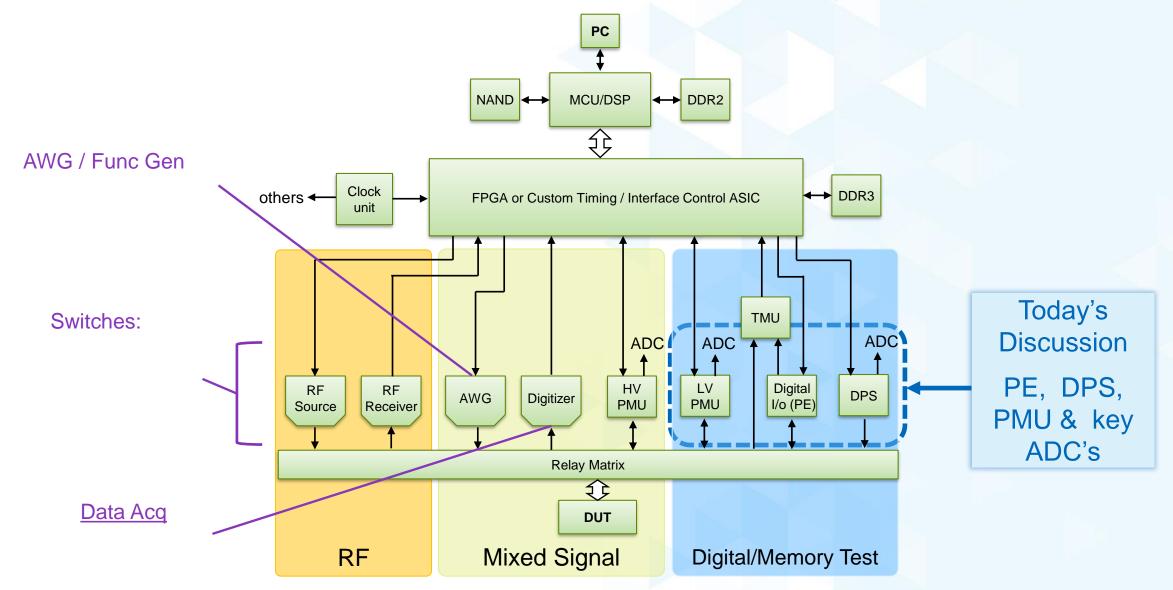
- LCD driver
- Automotive IC
- SoC
- IGBT

Memory

- DRAM
- SRAM
- EEPROM
- NAND/NOR Flash

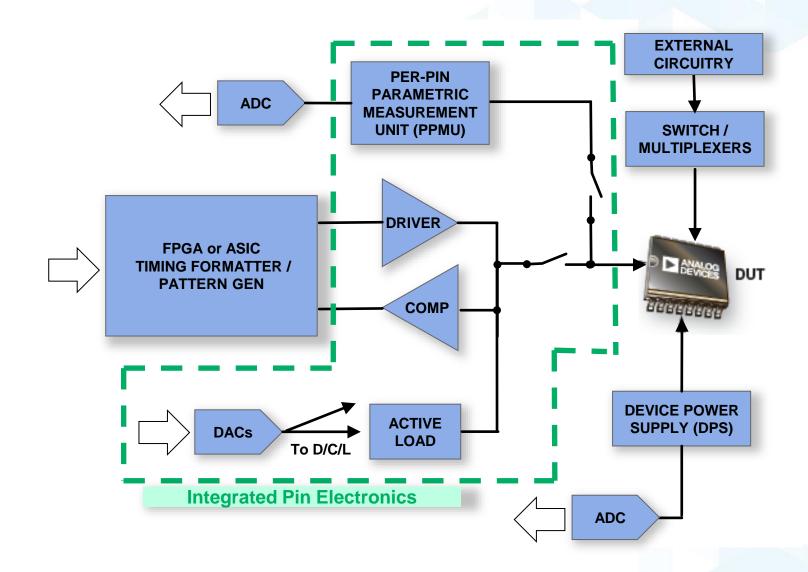
Additional Information / Links





Example Digital I/O Signal Chain

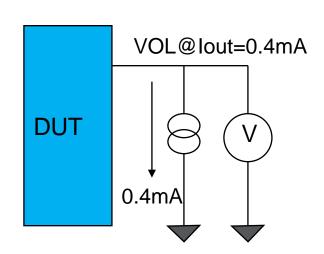


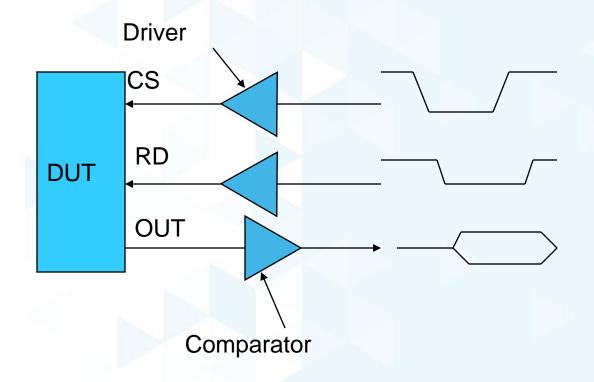


What Functions and Specs need to perform at ATE



- Functional Test: Open , short
- DC Parametric Test: VOH, VOL, IIH, IIL, Supply Voltage/Current (with PMU)
- AC function Test: Read/Write timing, Truth Table, Setup Time/Hold Time ..etc. (with DCL etc.)



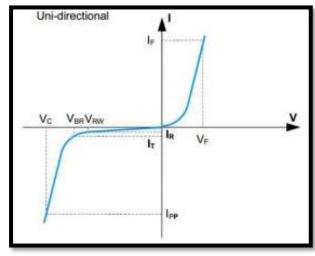


Who uses PMU? --- Parameter Measurement Unit

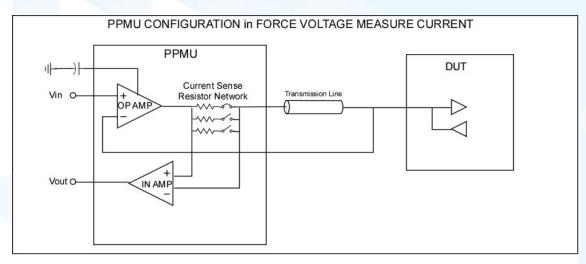


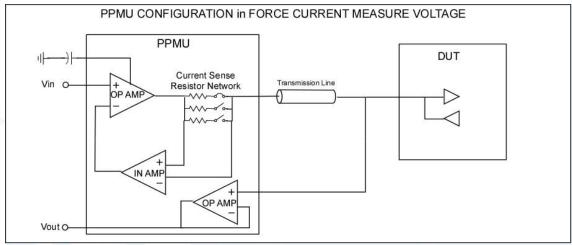
Instrument Boards:

- As a VI forcing current/voltage
- As a low current DPS without an external amplifier
- Or a high current DPS with an external amplifier
- Or as SMU (source/measure unit)



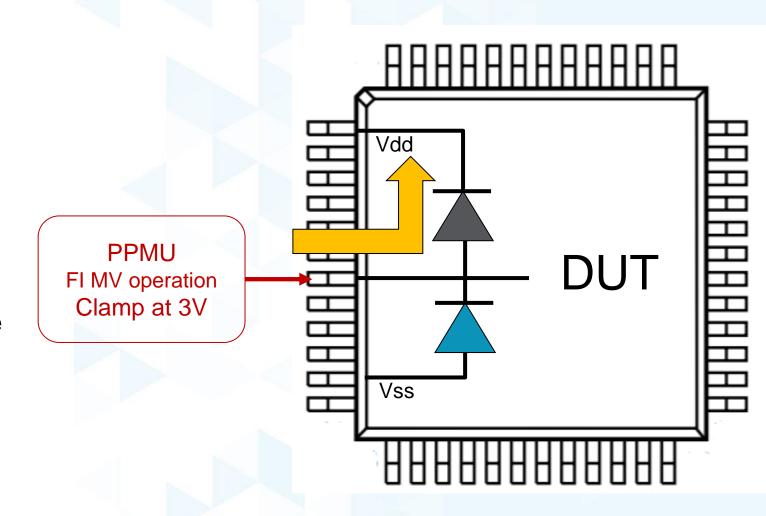
Diode I/V curve





PMU --- Open/Short test

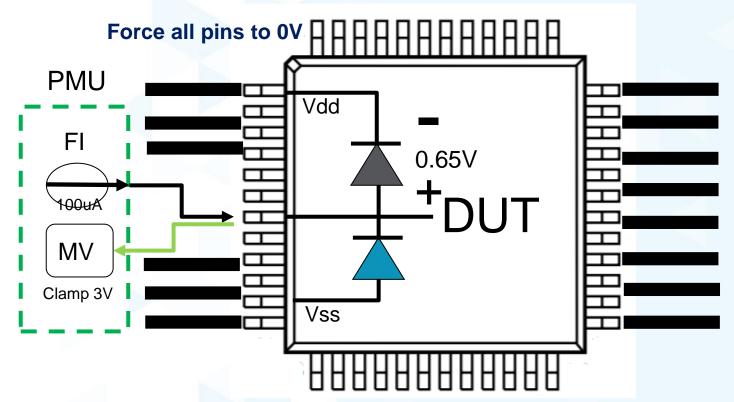
- Open/Short test
 - Continuity test
 - Contact test
 - Make sure the internal connection
- Upper diode and Lower diode
- Test the signal Pin and Power pin diode
- Test method
 - DC measurement
 - Pattern measurement



PMU --- FIMV with Clamp V function

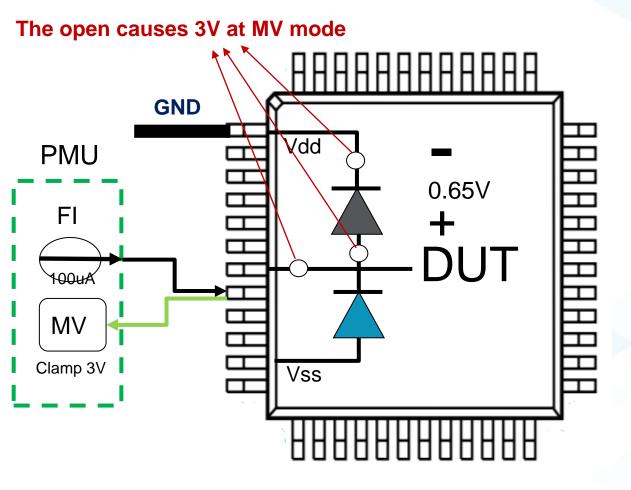


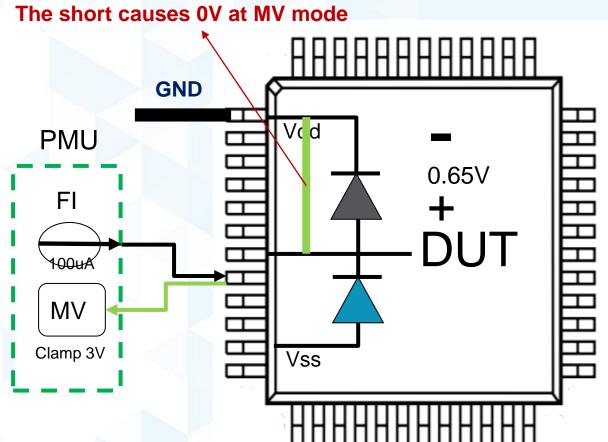
- Open/Short test step
 - Connect all pins to GND except for DUT pin
 - Force current 100uA to DUT pins
 - Set clamp as 3V
 - Measure the voltage
- Pass or Fail
 - Normal result is 0.65V
 - Open result is 3V
 - Short result is lower than 0.1V



PMU --- The result of Open or Short for Vdd diode



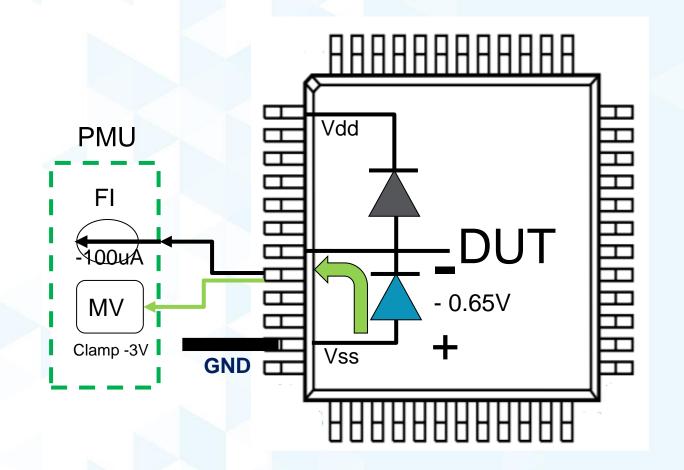




PMU --- Diode test



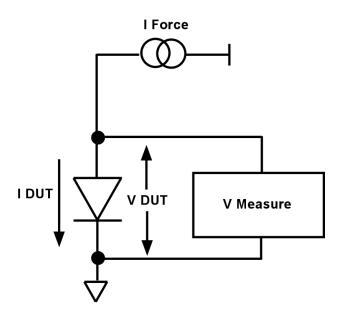
- Open/Short test step
 - Connect all pins to GND except for DUT pin
 - Force current -100uA to DUT pin
 - Set clamp as -3V
 - Measure the voltage
- Pass or Fail
 - Normal result is -0.65V
 - Open result is -3V
 - Short result is larger than -0.1V



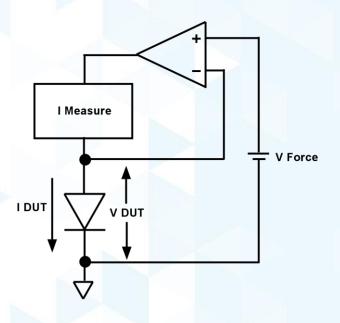
PMU --- How Does it Work



- Force Current Measure Voltage
 - Diode Testing, ESD Diodes on IC
 - Voltage Clamps provided when forcing current to protect DUT (Open Circuit)

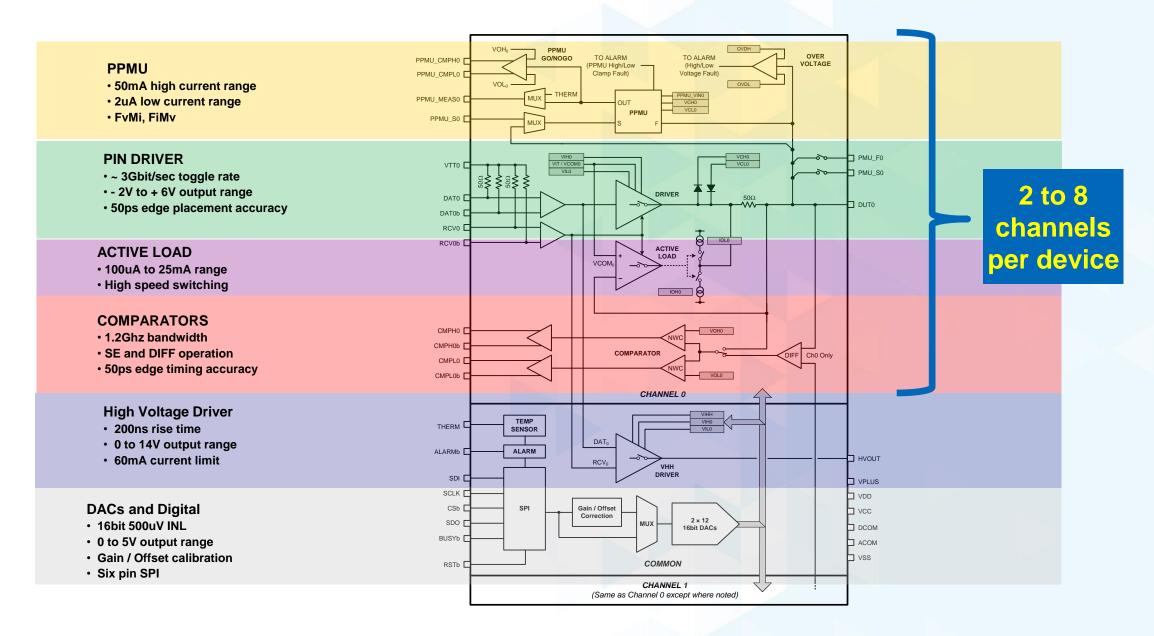


- Force Voltage Measure Current
 - Leakage Current Testing
 - Current Clamps to protect DUT when forcing voltage,
 Short circuit protection



ADATE3xx Block Diagram and Typical Key Features

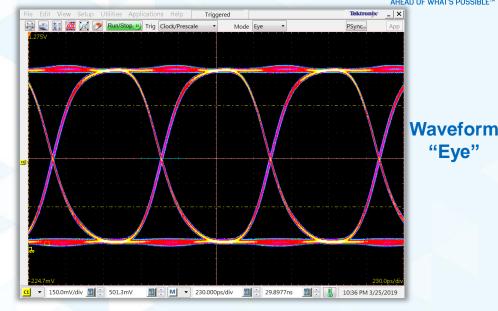




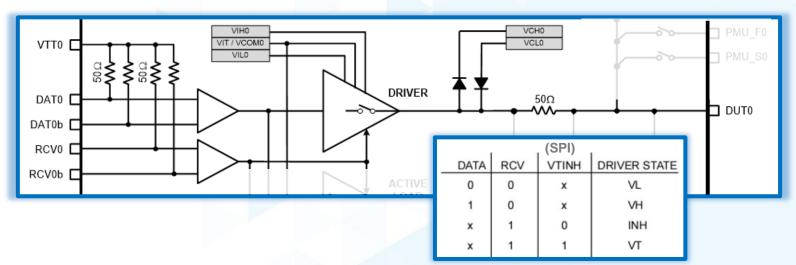
Driver

ANALOGDEVICES

- ADI's Driver waveforms provide superior fidelity
 - Waveform Integrity Key for High Performance
 - New Driver Architectures Speed, Power Density improvement
- Important Characteristics (with examples)
 - Timing accuracy / jitter
 - Voltage range (-1.5 to 6.5V)
 - Good waveform fidelity from Vswing low to high
 - Speed: x MHz to y GHz (sweet spot: 1.6GHz or 3.2Gbps)
 - Fast switching between modes
 - Cable Loss Compensation (CLC)
- Typical modes of operation:
 - Drive high level (VH)
 - Drive low level (VL)
 - Drive termination level (VT)
 - High impedance mode



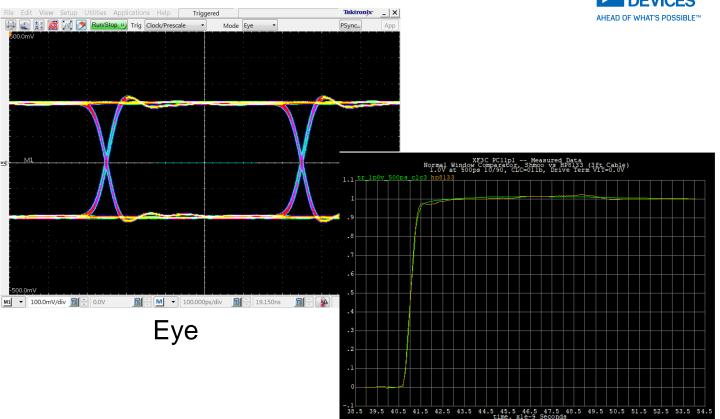
Example = 2V programmed, 1.5Gbps Very open Eye - Low Jitter (20ps p-p)

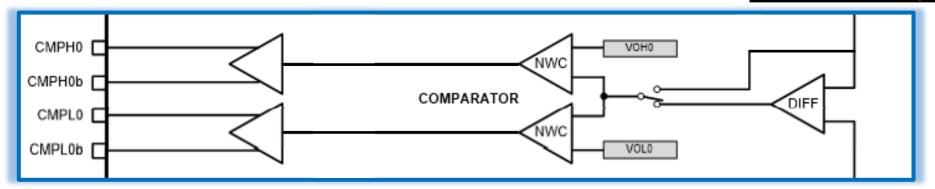


Comparator

ANALOG DEVICES

- Important Characteristics (with examples)
 - Dispersion: edge timing accuracy vs:
 - Input slew rate, overdrive, pulse width
 - Voltage range (-1.5 to 6.5V)
 - Input Analog Bandwidth
 - Speed / Shmoo Performance
- Modes of operation
 - Single-ended Compare
 - Window Compare
 - Differential Compare





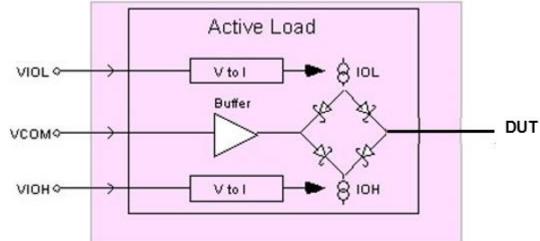
Shmoo

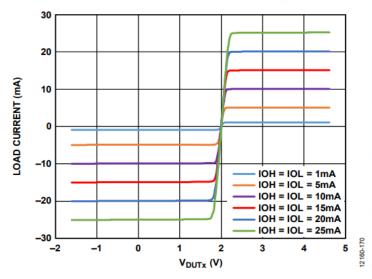
Ch 1

Active Load



- Provides a precise programable source and sink current load for testing the DUT's output VOH and VOL levels. This current can be varied over a wide range (100uA to 25mA).
- The load can also be used as a termination to test a DUT's output timing specifications into a low impedance.
- Important Characteristics (examples)
 - Maximum Current (100mA)
 - Voltage range (-1.5 to 6.5V)
 - Current accuracy
 - Fast switching between source and sink
 - Impedance (current flatness vs voltage)
 - Commutation voltage width (steepness)
- Modes of operation
 - Load Disable
 - Load Enable and Commutation

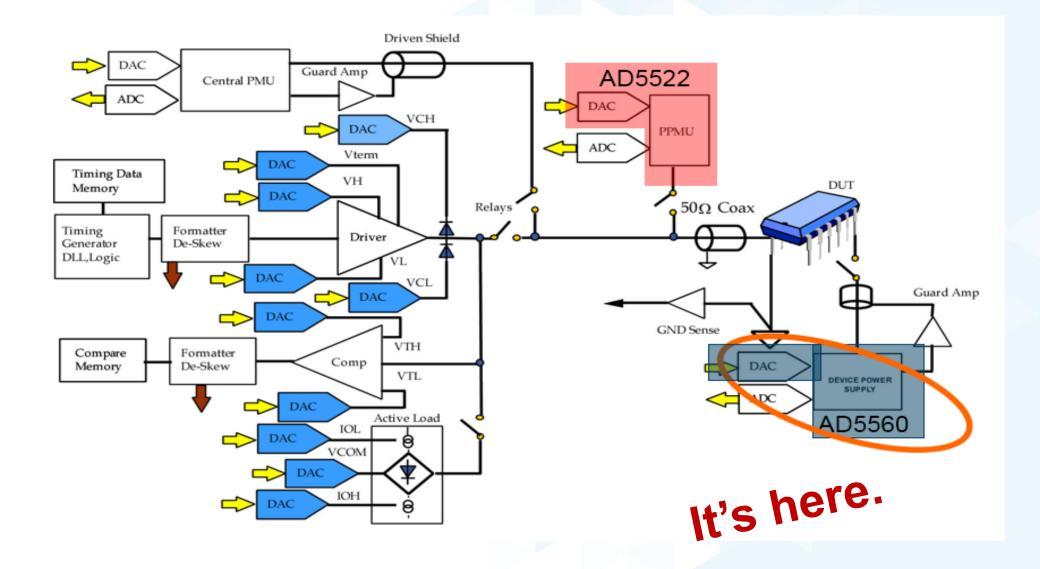




Active Load Commutation Response, VCOM = 2.0 V

Who uses DPSs?.....ATE Application



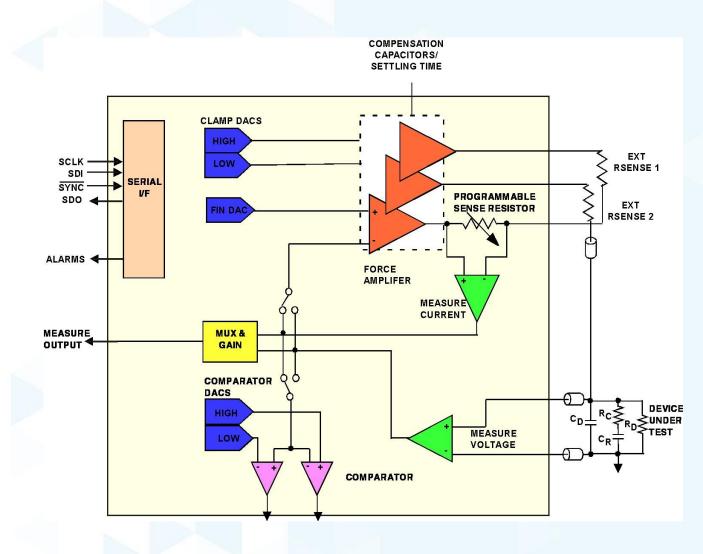


AD5560 Simplified Block Diagram



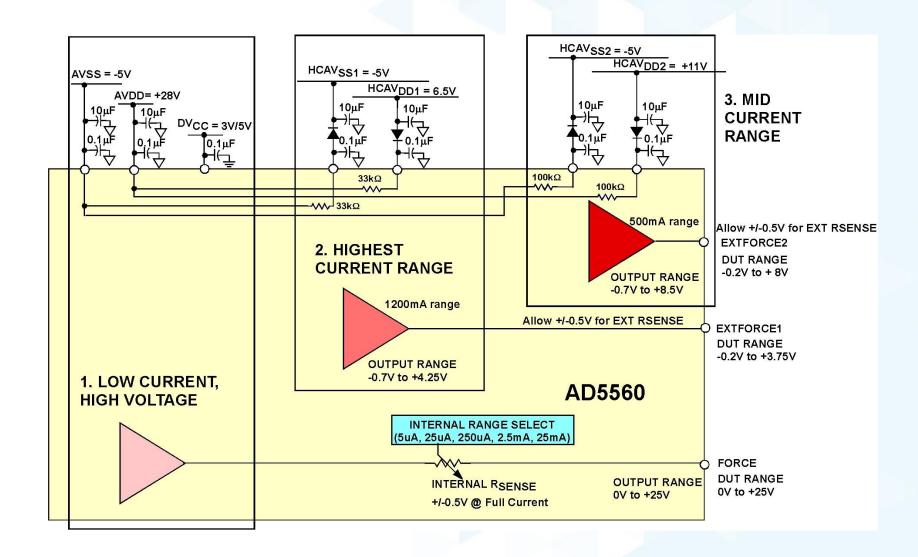
DEVICE POWER SUPPLY

- FV/MI Function
 - 25V Output Span, scalable + offsetable
 - 5 Current-ranges 5 uA, 25uA, 250uA, 2.5mA, 25mA (Rsense on-chip)
 - 2 High Current-ranges 500mA and 1.2A max (Rsense off-chip)
- MV Function
 - Measure DUT Voltage
- ON CHIP LEVELS
 - 16 Bit DACs (FIN, CPH, CPL)
 - 16 Bit DACs (CLL, CLH)
- Offset and Gain Calibration on Chip



AD5560 Supply Rails

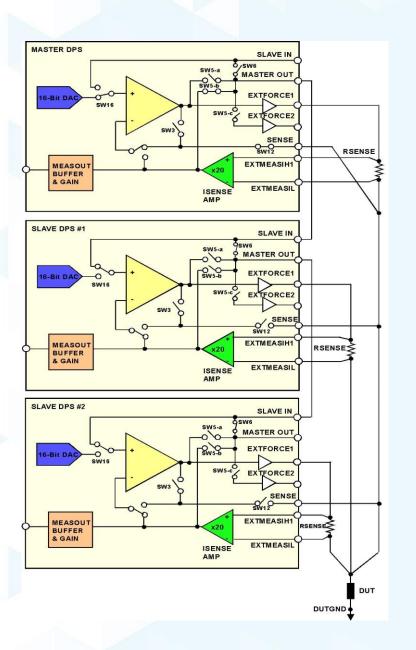




Need > 1.2A Current DPS?



- Currents in excess of 1.2A
- Master/Slave approach
 - 1 Master
 - Max 128 Slaves are verified



DPS/PMU Precision Voltage Measurement Solution AD5560 / AD5522 with a SAR ADC

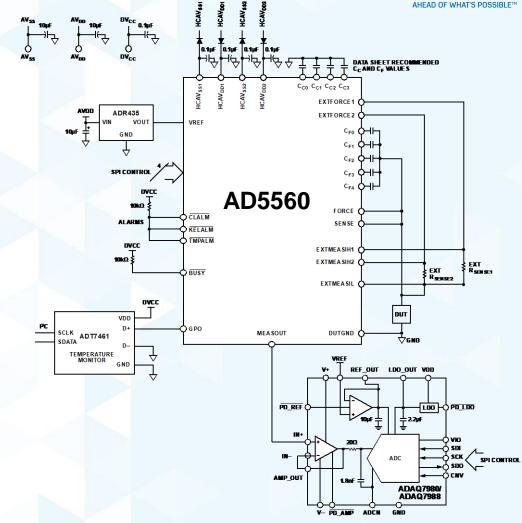
ANALOG DEVICES

AD5560: high performance, highly integrated device power supply

AD5522: Quad, high performance, highly integrated parametric measurement unit

- AD5560 / AD5522 prevalent in many large ATE solutions
- Sensed DUT Voltage or Current available on MEASOUT
 - Current Sense across either internal or external shunt resistor
 - ► Selectable Output Voltage Range (+/- 11V or 0 to VREF), VREF = 2.5 or 5.0V
 - Typically one output per source channel

Channels	Resolution	Output Range	Channels	Products
Multichannel	18	+/-11V	8	LTC2358/7/3-18 AD7609/8, AD7606C*
	16	+/-11V	8	LTC2358/7/3-16
	16	0 to VREF	8 16	AD7689 AD4696*
Single	18	0 to VREF	1	AD4006
	16	0 to VREF	1	ADAQ7980 AD4004

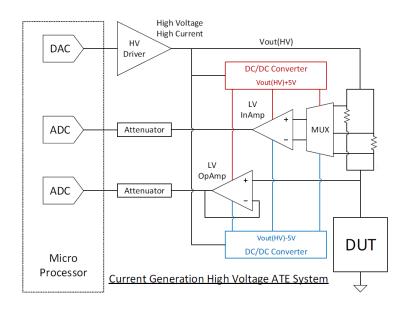




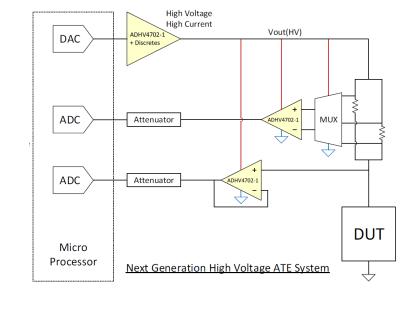
High Voltage Amplifiers

Automated Test Equipment (ATE): High-side Current Sensing





New ADI Products
Improved performance
Area savings

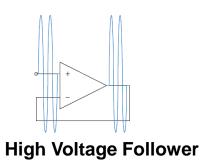


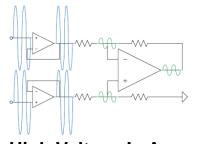
Key Benefits

- Eliminate switching noise from DC-DC converters
- Protect low voltage devices
- Minimize design area and complexity
- Breakthrough design improvements:
 - >100V Input common-mode and output Swing
 - High input impedance
 - High precision over temperature

Recommended Products

- ADHV4702-1: 220 V Span Precision Amplifier
- LT6090/LT6090-5: 140V CMOS Rail-to-Rail Output, Picoamp Input Current Op Amp



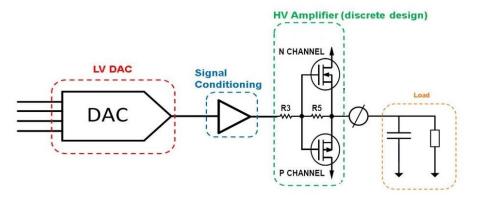


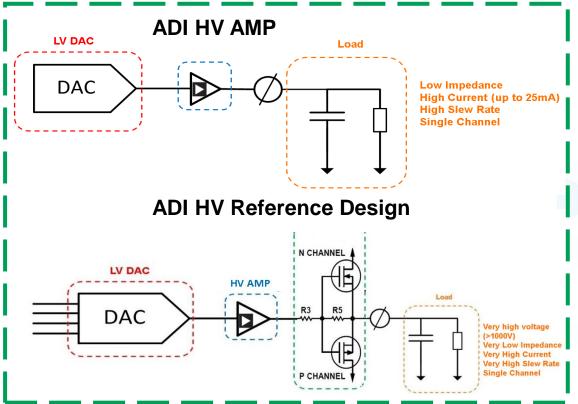
High Voltage In Amp

High Voltage Driver

High Voltage Driver: Piezo Transducer driver







Key Benefits:

- Small solution size with high energy efficiency
- 200V or higher output swing
- Exceptional capacitive or low resistive load drive
- Up to 1A current drive
- High slew rate

Recommended Amplifiers :

- ADHV4702-1: 220 V Span Precision Amplifier
- ADA4870: 10V to 40V, High Speed,1 A Output Drive Amplifier
- ADA4700-1: +/-5V to +/-50V, Precision Operational Amplifier

Recommended Reference Designs :

- ADHV4702-1 Current Booster: 220V, 1A Output Drive, Precision Reference Design
- ADA4870 Voltage Extender: 70V, 1A Output Drive, High Speed Reference Design

ADHV4702-1 24 V to 220 V Precision Operational Amplifier



FEATURES

Wide range of operating voltages

Dual-supply: ±12 V to ±110 V

Asymmetrical supply operation: 24 V to 220 V

Wide input common-mode voltage range: 3 V from rails

High common-mode rejection ratio: 160 dB typical

High Aol: 170 dB typical

High slew rate

74 V/µs typical

24 V/µs typical with external input clamping diodes

Low input bias current: 2 pA maximum

Low input offset voltage: 1 mV maximum

Low input offset voltage drift: 2 μV/°C maximum

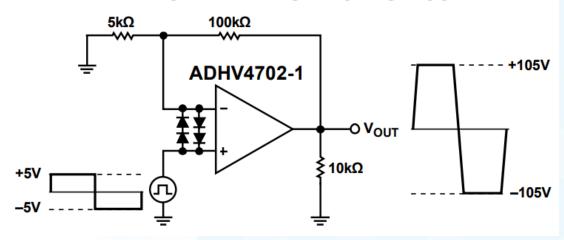
Low input voltage noise: 8 nV/√Hz typical at 10 kHz

Wide small signal bandwidth: 10 MHz typical

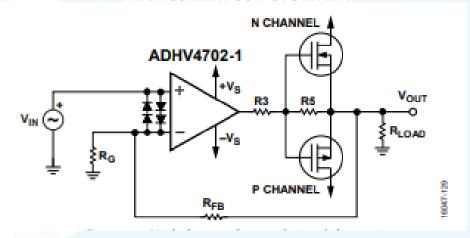
Resistor adjustable quiescent current: 0.6 mA to 3 mA ($V_s =$

±110 V)

TYPICAL APPLICATION CIRCUIT



HIGH CURRENT OUTPUT DRIVER





ADGS SPI Controlled Switch/Multiplexer Family

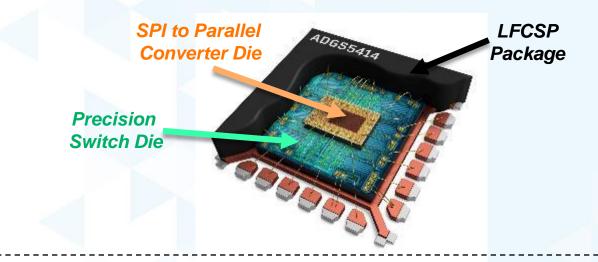
ADGS Family (Nine Generics) For High Density Applications

>20% Board Density Improvement





- SPI integration with existing parallel switches/multiplexers
 - Part names retained with an S added to signify SPI control
 - Example: ADG1412 updated to ADGS1412
- Industry-leading precision switch performance retained
- ▶ Three modes of SPI operation
 - Daisy-chain mode
 - Addressable mode with CRC error detection (new mode)
 - Round Robin mode (new mode)
 - (Cycle within a mux with comparable speed to a parallel interface)
- Additional GPO pins to control additional parallel devices (such as ADI switches)
- Break before make switching allows switch to be configured into mux



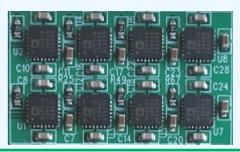
Precision SPI Switch Configuration Increases Channel Density

May 2017 Analog Dialogue Article



8x ADG1412 with Port Expanders

Overall 20% Board Area Reduction



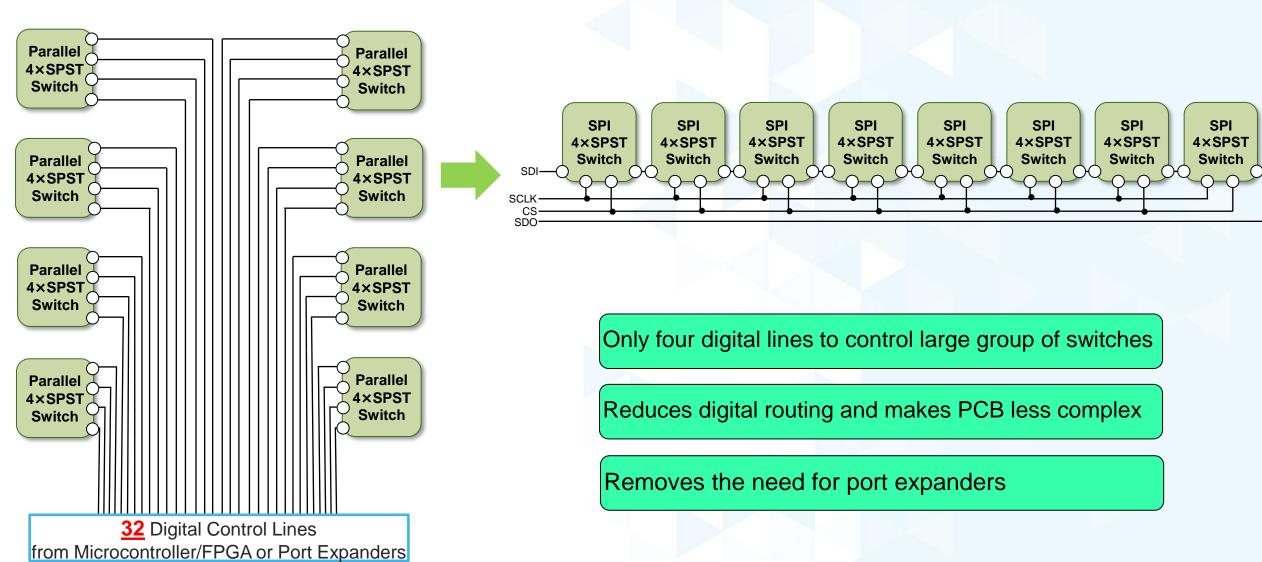
8× ADGS1412 in Daisy-Chain Mode

Removes Port Expanders and Reduces Digital Routing



Increasing Channel Density Using Daisy-Chain Mode





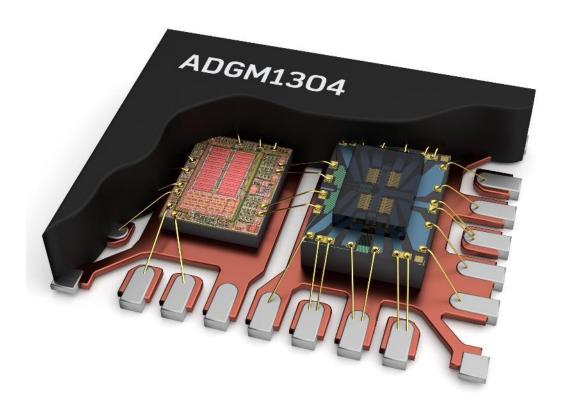




MEMS Switch

MEMS Switch Technology Overview





System Benefits

- Widest band performance—precision DC to GHz
- Lowest loss switching
- Highest signal integrity—low harmonic distortion

Additional Benefits vs. Mechanical Relays

- 20x smaller
- 30x faster
- 10× reduction in power requirements
- 100x longer cycle lifetime

- ▶ New Technology, Business, and Market for ADI
 - Displaces incumbent unreliable bulky relays



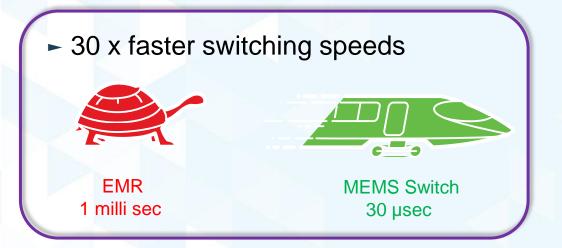
ADGM1304 & ADGM1004 Key Benefits I



Compared to a Typical RF Electromagnetic Relay

► 20 x smaller size

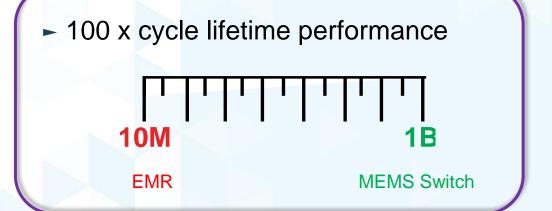




► 10 x reduction in power requirements





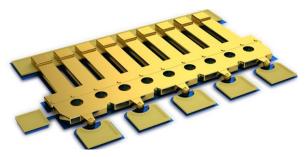


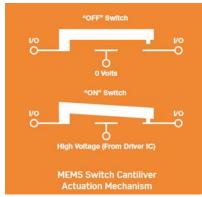
ADGM1304/ADGM1004: MEMS Switch Product Overview



Micromechanical structure

- Cantilever beam design
- Complete internal to ADI manufacturing process
- Manufactured in a sub-micron semiconductor Class 1 clean room





No dry-switching limitations

Hermetically sealed

Ease of use

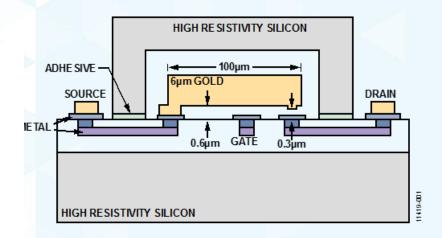
Co-packaged MEMS switch and driver IC





Step change in relay replacement

- ADGM1304/ADGM1004 devices specified fully from 0 Hz/DC to 14 GHz
- Reliable, fully qualified products in tiny form factor

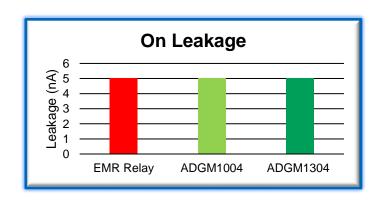




ADGM1304 & ADGM1004 Key Applications in ATE environment

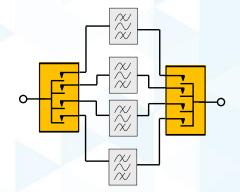


- Load / probe board applications
 - Arbitrary Waveform / RF Generators, Digitizers
 - Mixed signal switching, Voltage divider network switching, Filter network switching, General Digital routing
- Switch matrix applications
 - RF signal routing and RF signal fan out board
- Key leakage specification not compromised



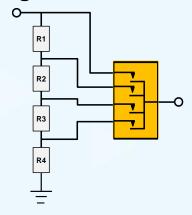


Filter Switching





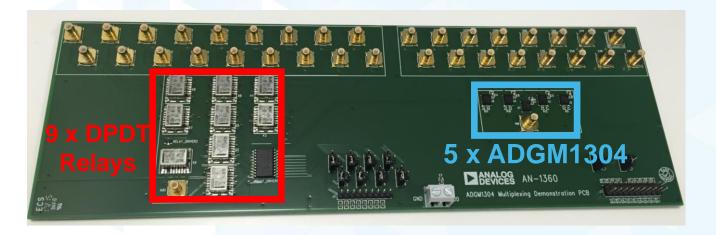
Voltage Divider Network



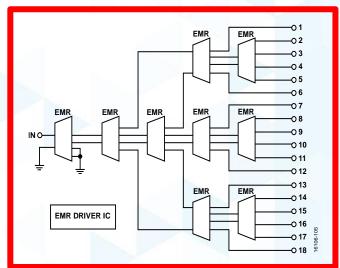
Switch Matrix Application- What's the value of MEMS switch??



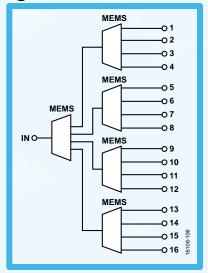
- Switch matrix board (1:16 or 16:1 multiplexer) comparison
 - EMR Solution = 9x DPDT relays & Driver
 - MEMS Solution = 5 x SP4T MEMS switch
- System Key value points:
 - 68% reduction in area and 95% reduction in volume
 - Reduce complexity- SP4T RF tracking simplification
 - Allowing Dual side placement (low profile 1mm height)
 - 15mA (5xADGM1304) versus 270mA (9xDPDT relays) peak driver power consumption
 - No simultaneous cycling restriction due to ultra high power requirements.



Using EMR Switches



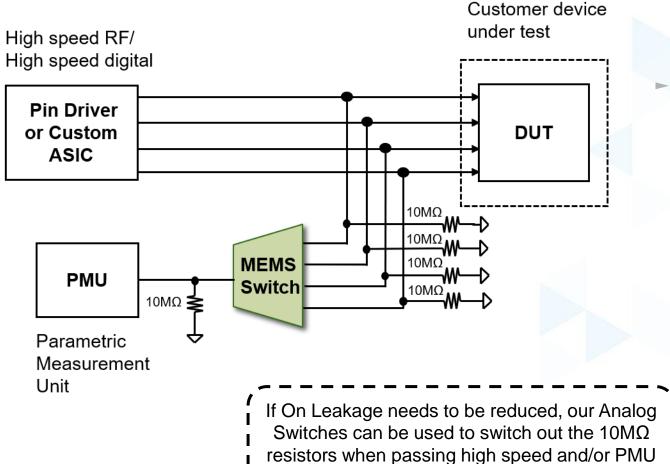
Using ADGM1304 MEMS Switches



Typical ATE application



PMU Switching



signals

Key values brought by MEMS switch

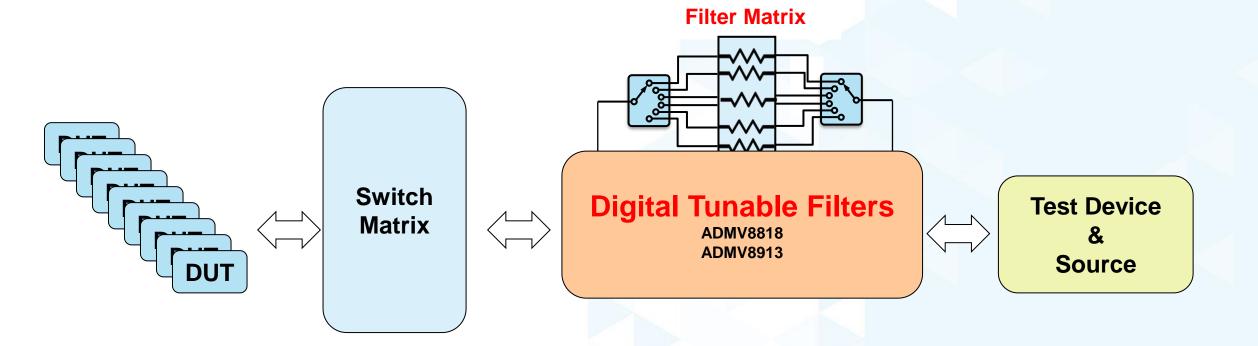
- Ultra low insertion loss
- Operational from DC to high frequencies
- Specified to pass DC voltage up to +/-6V
- Ultra small size (5mm x 4mm x 0.95mm)
- Minimum Lifetime of 1Billion actuations



Digital Tunable Filters

Filter Matrix



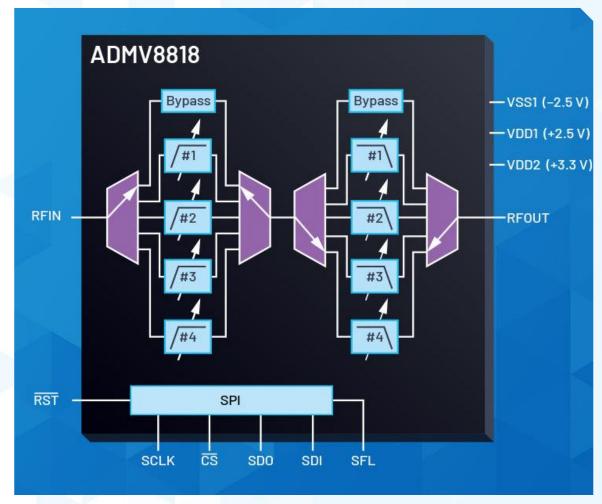


ADMV8818: 2 GHz to 18 GHz, Digitally Tunable High-Pass/Low-Pass/Band-Pass Filter



Value Proposition

- Reconfigurable filter that can serve multiple roles in a signal chain
- Single-chip replacement for discrete solutions
- Includes on-chip lookup table for fast frequency hopping applications
- Enables low SWaP-C (size, weight, power, and cost) solution
- Key Benefits
- Flexible, digitally controlled multi-octave tuning
- Independent 3 dB frequency controls for up to 4 GHz of bandwidth
- Digital switched capacitors improve filter linearity and frequency response compared to varactor-based solutions
- Extended operating temperature range (–55°C to ~+105°C)



ADMV8913: X-Band, Digitally Tunable High-Pass Filter and Low-Pass Filter

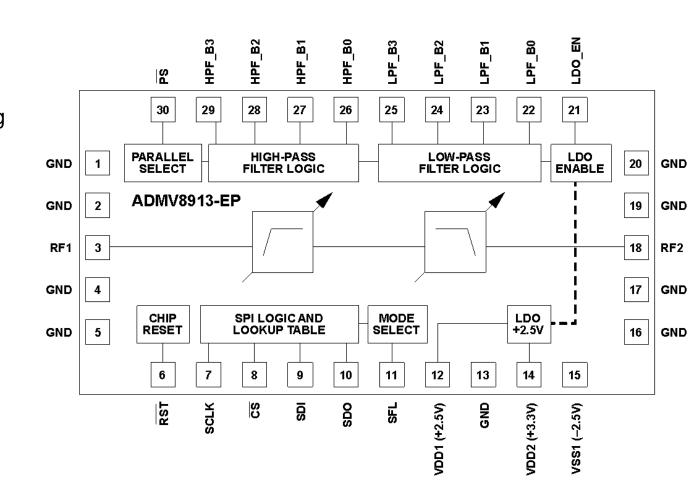


Value Proposition

- Single-chip tunable band-pass filter replacement for discrete solutions
- Includes on-chip lookup table for fast frequency hopping applications
- Enables low SWaP-C (size, weight, power, and cost) solution
- ► Flexible parallel and serial control interface option

Key Benefits

- Flexible digitally controlled tuning and low insertion loss
- Independent high-pass and low-pass filter 3 dB frequency controls for up to 4 GHz of bandwidth
- Digital switched capacitors improve filter linearity and frequency response compared to varactor-based solutions
- Integrated LDO regulator to reduce overall BOM
- Extended operating temperature range (–55°C to ~+105°C)



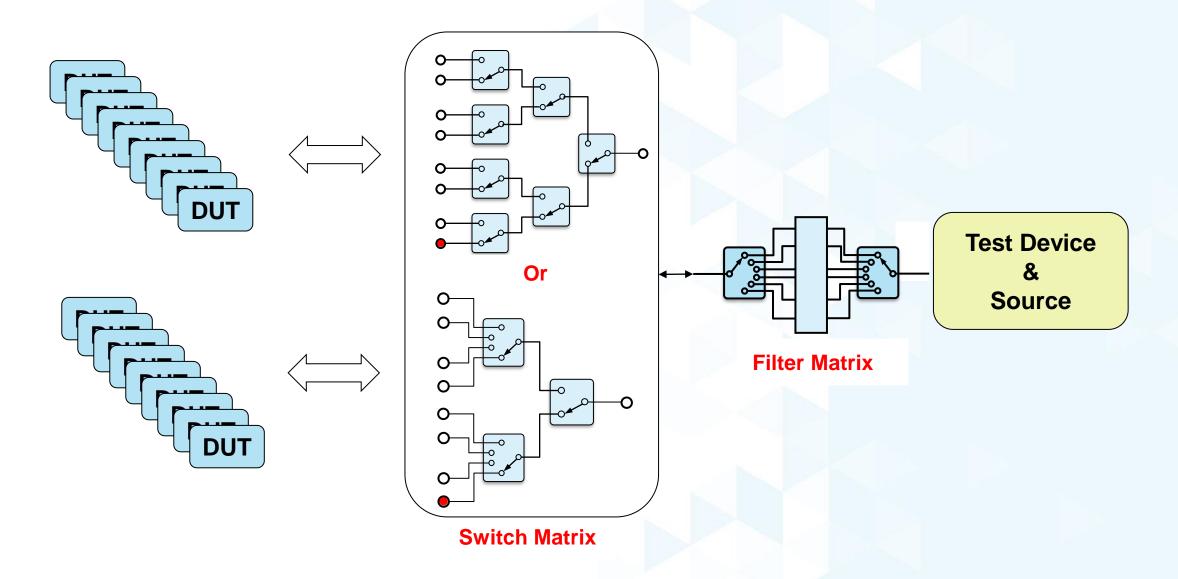




High Frequency >30GHz RF Switch

High Frequency Application





SWITCHES (Key Parameters)

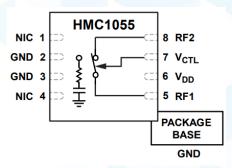


SWITCHES

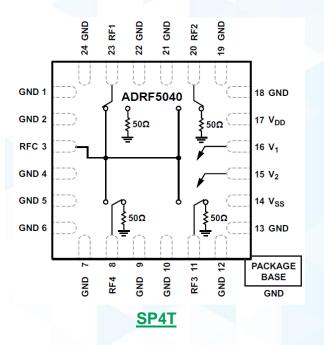
- Frequency Band
- Insertion Loss (dB)
- Isolation (dB)
- Configuration
 - SPST, SPDT, SP3T, SPxT
 - Switch Matrix (Example 4x2)

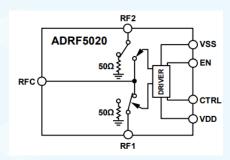
HOT PRODUCTS

- ADRF5020 (Si SPDT, 0.1-30GHz)
- ADRF5021 (Si SPDT, 9kHz-30GHz)
- ADRF5024 / ADRF5026 (0.1-44GHz)

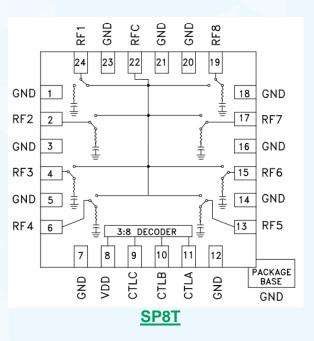


SPST (Single Pole – Single Throw)





SPDT (Single Pole – Double Throw)



SPDT Switches



Part Number	Description	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	Input P1dB (dBm)	Input P0.1dB (dBm)	Input IP3 (dBm)	On/Off Time	Control Input (V _{DC})	Package (mm)
ADRF5021 * ^	Nonreflective	9 kHz to 30	2	60	_	27	52	1.1 µs/1.1 µs	CMOS/LVTTL	3 × 3 LGA
ADRF5020 * ^	Nonreflective	0.1 to 30	1.4	56	27	_	50	10 ns/10 ns	0/3.3	3 × 3 LGA
ADRF5300_ ^	SPDT with no neg. supply	24 to 32	1.1	38	_	37	65	60 ns/60 ns	CMOS/LVTTL compatible	3 × 3 LGA
ADRF5025 *	SPDT, reflective	9 kHz to 44	1.4	36	_	27	50	1.7 µs/1.7 µs	0/3.3	2.25 × 2.25 LGA
ADRF5027 *	SPDT, nonreflective	9 kHz to 44	2.2	48	_		54	3.6 µs/3.6 µs	0/3.3	3 × 3 LGA
ADRF5024 * #	SPDT, reflective	0.1 to 44	1.4	38	_	27	50	10 ns/10 ns	0/3.3	2.25 × 2.25 LGA
ADRF5026 * #	SPDT, nonreflective	0.1 to 44	2.4	50	26	_	53	14 ns/14 ns	0/3.3	3 × 3 LGA
<u>HMC986A</u> *	Reflective	0.1 to 50	1.7	36	25	21	40	11 ns/11 ns	0/–3	Die

SP3T, SP4T, SP6T, SP8T Switches

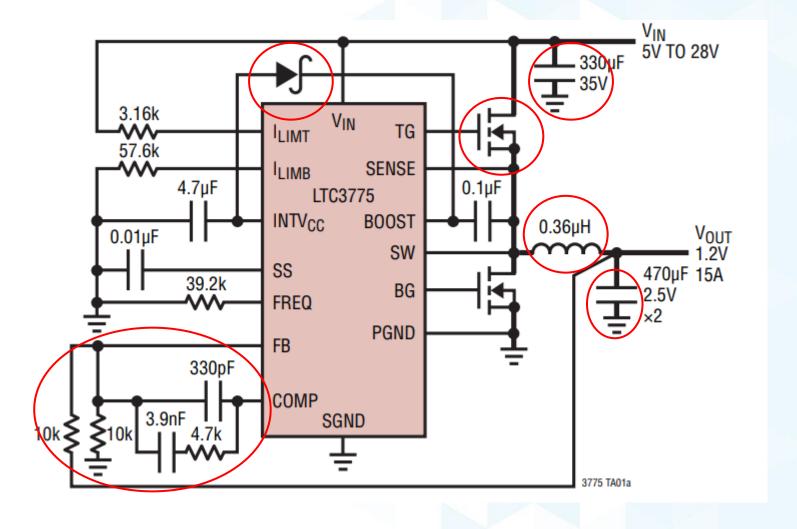
Part Numbe	er Description	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	Input P1dB (dBm)	Input P0.1dB (dBm)	Input IP3 (dBm)	On/Off Time	Control Input (V _{DC})	Package (mm)
ADRF5043	SP4T, nonreflective	9 kHz to 44	2.4	39	27	26	48	2.8 µs	0/3.3	3 × 3 LGA
ADRF5047	* SP4T, reflective	9 kHz to 44	2.4	33	1	26.5	50	3.4 µs/3.4 µs	0/3.3	3 × 3 LGA
ADRF5042	SP4T, nonreflective	0.1 to 44	2.8	39	27	26	47	14 ns	0/3.3	3 × 3 LGA
ADRF5046	* SP4T, reflective	0.1 to 44	2.5	33	_	27.5	50	16 ns/16 ns	0/3.3	3 × 3 LGA



uModule Power

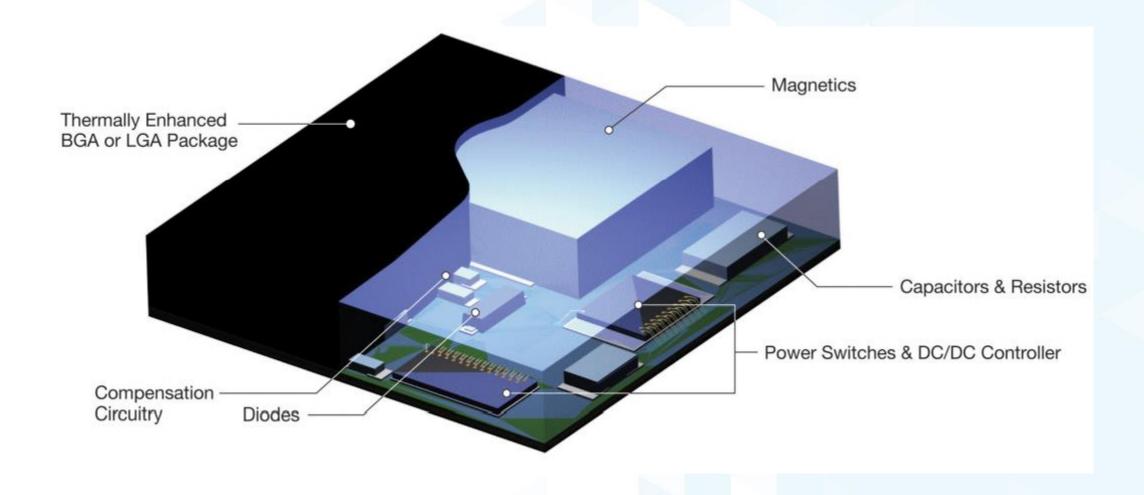
Step-Down Switching Regulator Stracture





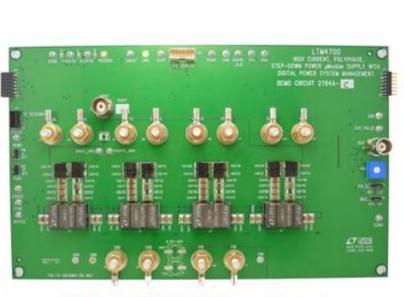
ADI uModule



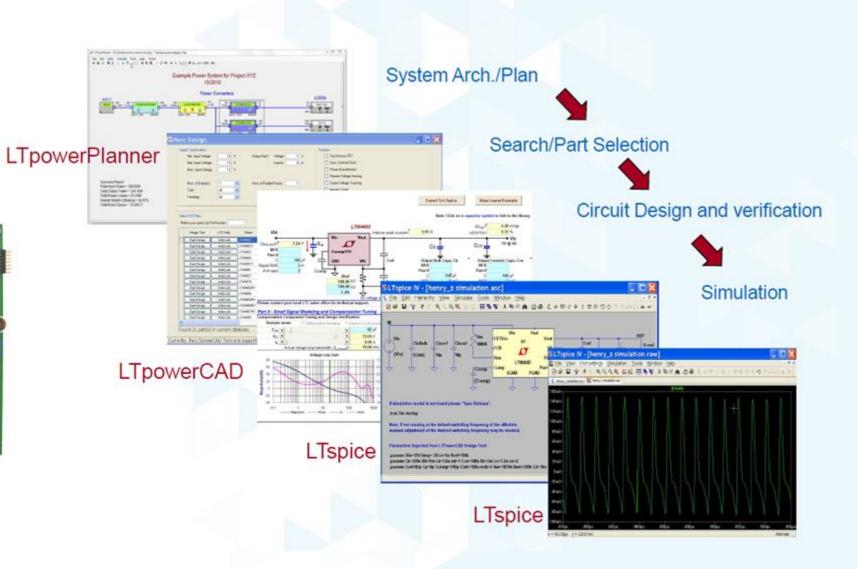


ADI Design Support





400A 4x LTM4700 Demo Board



Innovation-µModule



Year 2010

12x LTM4601

Year 2012

4x LTM4620

Year 2014

3X LTM4630

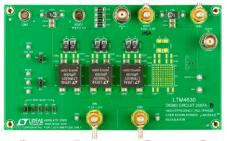
Year 2016

2x LTM4650



FPGA Core 0.8V @100A Power Supplier Solution







1 x LTM4700 with *Digital Telemetry* (July 2018)

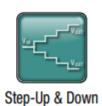


ADI µModule Family





















Step-Up

Isolated

Management

Inverting

Battery Charger



Multiple Output



Ultrathin



Low V_{IN} (≤3V)



Pin Compatible



Low EMI



Wide Temperature



SnPb BGA

Adjustable Loop Compensation



Margining



Sequencing & Margining



Precision Remote Sense

Ultrathin µModule Regulators

(Thickness: 1.18mm, 1.82mm, 1.91mm)



















11 x 16 x 1.82mm

16 x 16 x 1.91mm

15 x 9 x 1.82mm

LTM4686

with PSM

LTM4631 Dual 10A or Single 20A Dual 10A or Single 20A

LTM4643 Quad 3A

> LTM4623 Single 3A

LTM4632



6.25 x 6.25 x 1.82mm

LTM4622 Dual 2.5A or Single 5A

Triple output for DDR/QDR





LTM4668/ LTM4668A Quad 1.2A

LTM8074 40Vin, 1.2A



LTM4691 Dual 2A

LTM4700 Single 100A / Dual 50A µModule with Power System Management

FEATURES

- Dual 50A Digitally Adjustable Outputs with Digital Interface for Control, Compensation and Monitoring
- Wide Input Voltage: 4.5V to 16V
- Output Voltage Range: 0.5V to 1.8V
- ±0.5% Maximum DC Output Error Over Temperature
- ±2.5% Current Readback Accuracy
- Integrated Input Current Sense Amplifier
- 400kHz PMBus-Compliant I²C Serial Interface
- Supports Telemetry Polling Rates Up to 125Hz
- Integrated 16-Bit ΔΣ ADC
- Constant Frequency Current Mode Control
- Parallel and Current Share Multiple Modules
- 15mm × 22mm × 7.82mm BGA Package

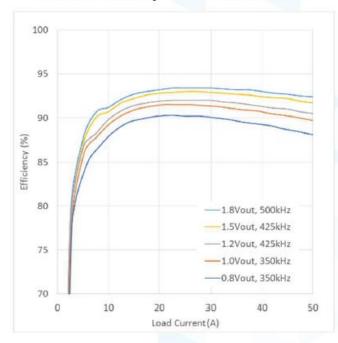
Readable Data:

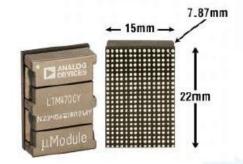
- Input and Output Voltages, Currents, and Temperatures
- Running Peak Values, Uptime, Faults and Warnings
- Internal EEPROM and Fault Logging with ECC

Writable Data and Configurable Parameters:

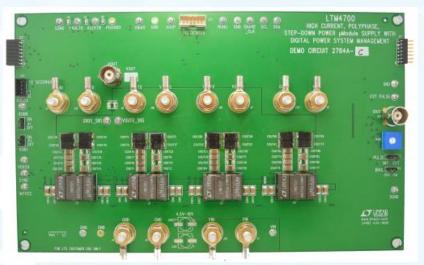
- Output Voltage, Voltage Sequencing and Margining
- Digital Soft-Start/Stop Ramp
- Optimize Analog Loop Compensation
- OV/UV/OT, UVLO, Frequency and Phasing

90% Efficiency at 12Vin to 1Vout









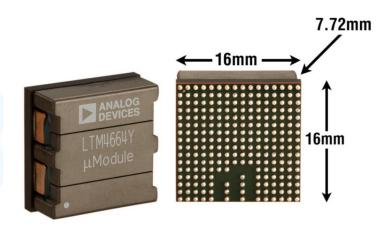
LTM4700: 400A Demo Board

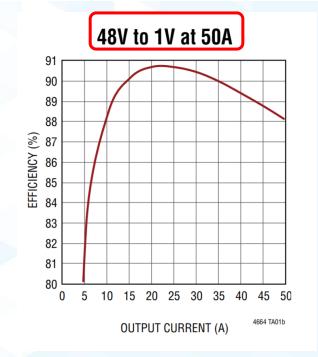
LTM4664 54V To Core Voltage Single 50A/Dual 25A µModule with I2C PMBus



FEATURES

- Complete 48V Input to Low Voltage Dual 25A Supply that Can Scale to 300A
- Dual Analog Loops with Digital Interface for Compensation, Control and Monitoring
- Input Voltage Range: 30V to 58V
- Output Voltage Range: 0.5V to 1.5V
- ±3% Output Current Readback Accuracy (-20° to 125°C)
- 88% Efficiency for 48V to 1V at 50A
- ±0.5% Output Voltage Accuracy Over Temperature
- 400kHz PMBus-Compliant I²C Serial Interface
- 16mm × 16mm × 7.72mm BGA Package





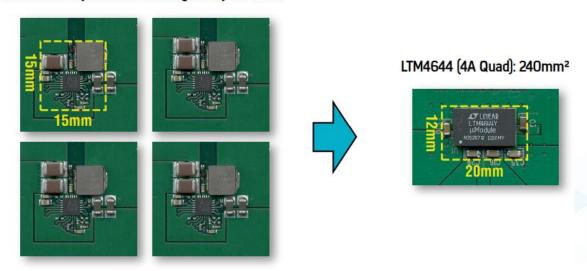
LTM4644 Quad 4A Step-Down uModule



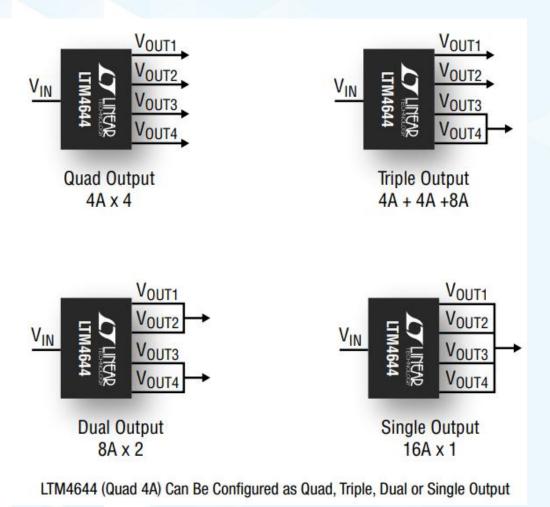
Example: LTM4644 Quad 4A Step-Down µModule Regulator 9mm x 15mm Package

Reduce solution size up to 73%

LTC3605 x 4 (4A Monolithic Regulator): 900mm²



Comparison Between LTM4644 (Quad 4A) and Discrete Solution (LTM3605 x 4pcs). The LTM4644 is 73% Smaller





END Thank you for join the sharing.

