

32x32 Switch Array For Driving a Deformable Mirror With Voltage-Resolution Beyond 16-bit

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Introduction

Application Background:

Switch multiplexing is considered a power saving approach for driving a high-actuator-count stacked deformable mirror in space

Main advantages of multiplexing driving:

- Save power
- Reduce wire connections
- Reduce mass
- Save cost

Highly off-isolation is required for achieving high Contrast:

- At least -96.3dB or 16-bit voltage-resolution

Limitations of the current HV switch arrays in the market

- Channel number: up to 32
- Voltage-resolution: ≤ 12 -bit

Critical Switch Parameters

Unit Circuit: Sample & Hold

- On-resistance

$$R_{on} \leq \frac{t_s}{0.693nC_{load}}$$

- Leakage

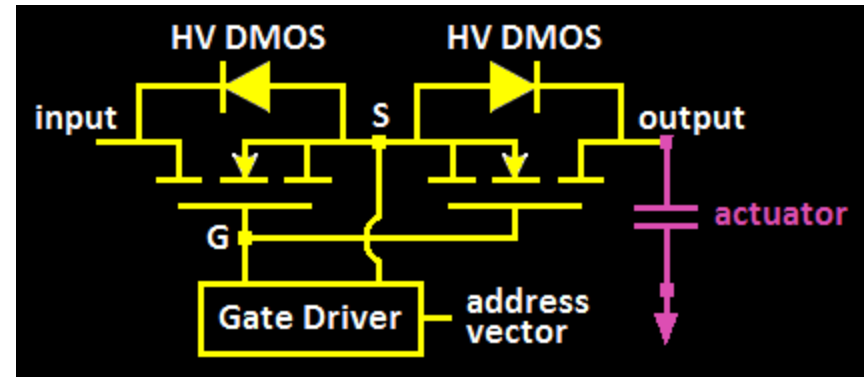
$$I_{leak} \leq \frac{C_{load}V_{max}}{2^n t_{frame}}$$

- Feedthrough or Off-isolation

$$C_{feed} \leq \frac{1}{2^n} C_{load} \quad K_o = 20 \log_{10} \left(\frac{\Delta V_o}{\Delta V_{in}} \right)$$

For an example: $n=16$, $C_{load}=50\text{nF}$, $V_{max}=100\text{V}$, $t_{frame}=1\text{s}$, $N=1024$

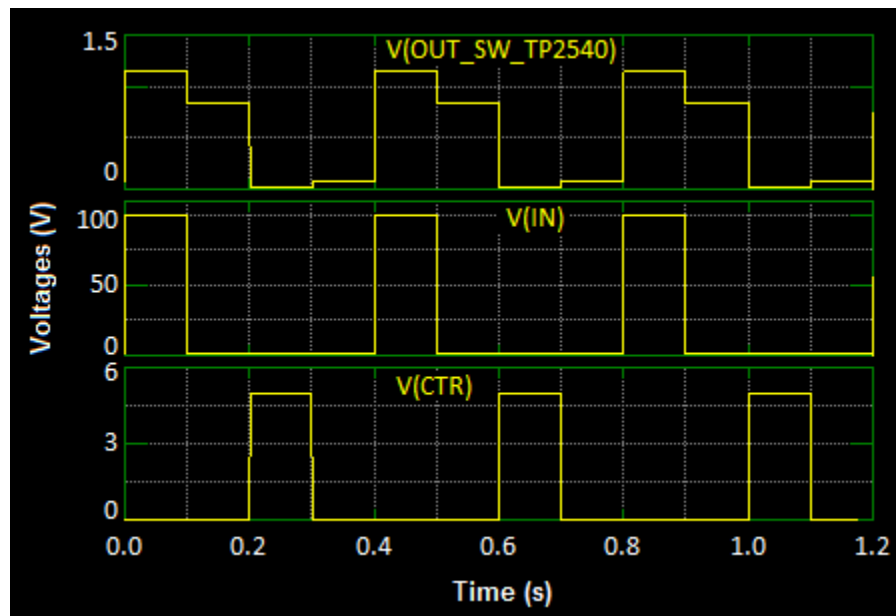
$R_{on} < 1.8\text{k}\Omega$ $I_{leak} < 38\text{pA}$ $C_{feed} < 0.76\text{pF}$ $K_o < -96.3\text{dB}$



Structure of an Analog HV Switch

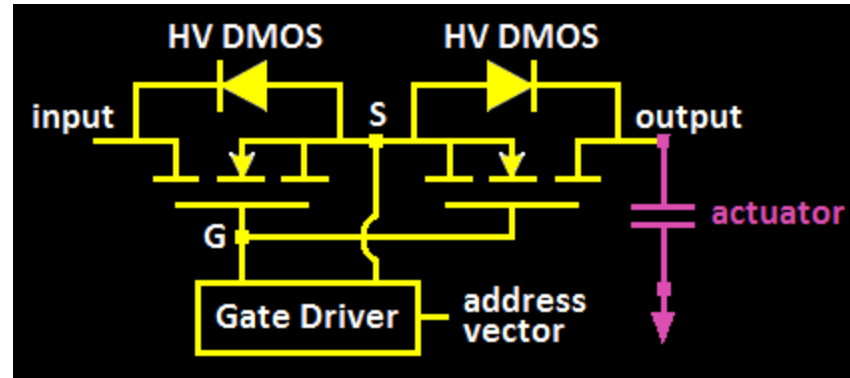
Critical Switch Parameters-continued

Main issue: Switch feedthrough



Simulated feedthrough of SW_TP2540 with
Clad=1nF; Cfeed=11pF when input changed
from 0 to 100V, 3pF when from 100 to 0V

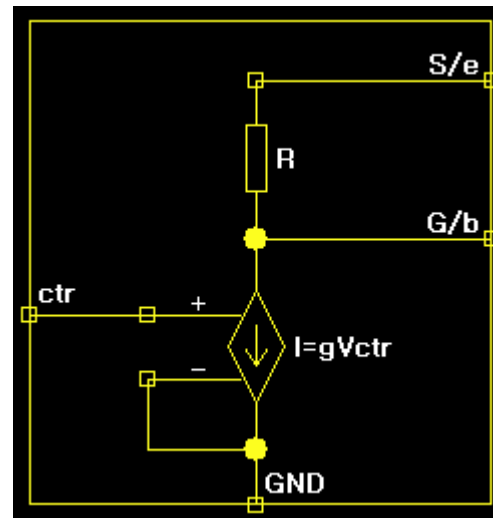
Main Techniques Need To Be Resolved



Structure of an HV analog switch

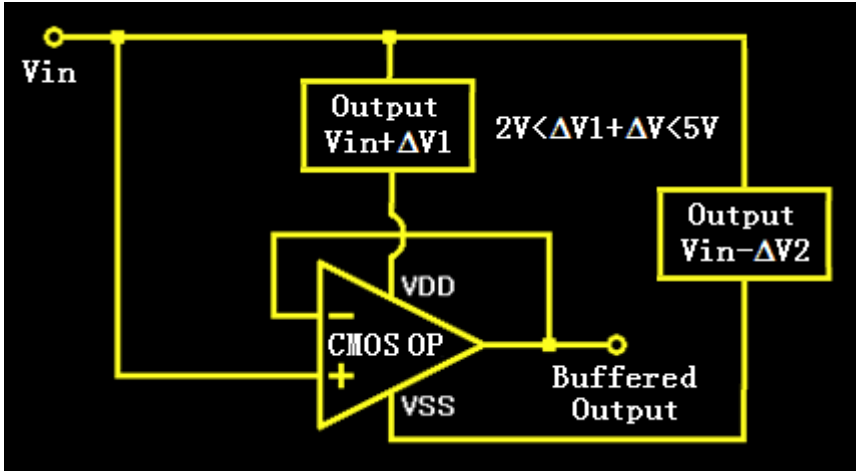
- A gate driver for configuring a bidirectional HV analog switch
- An HV buffer for directly monitoring a capacitive load signal
- An HV transistor featuring low leakage & low on-resistance
- An HV switch featuring feedthrough decoupled

Gate Driver

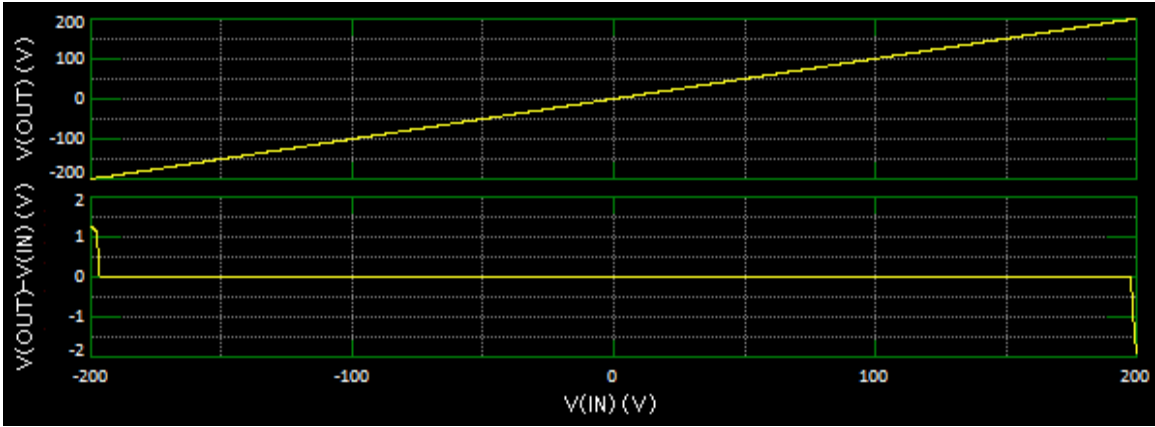


A simplified digital controlled level shifting driver

High-Voltage Unity-Gain Buffer Featuring Ultra-High Input Impedance



Principle Diagram

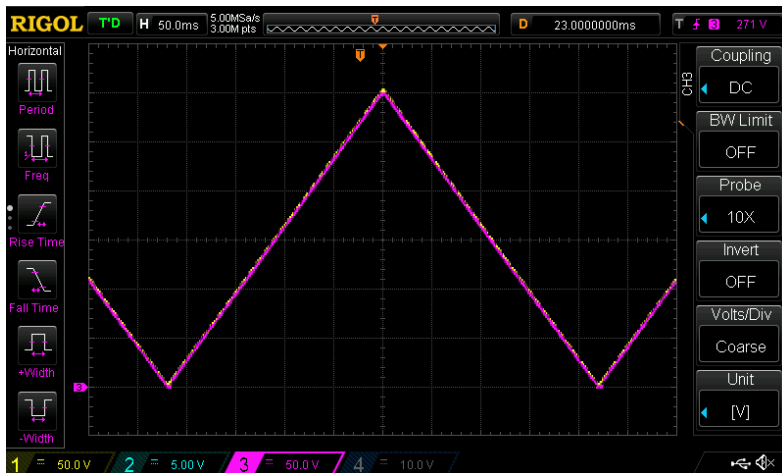


Simulation

High-Voltage Unity-Gain Buffer Featuring Ultra-High Input Impedance-continued

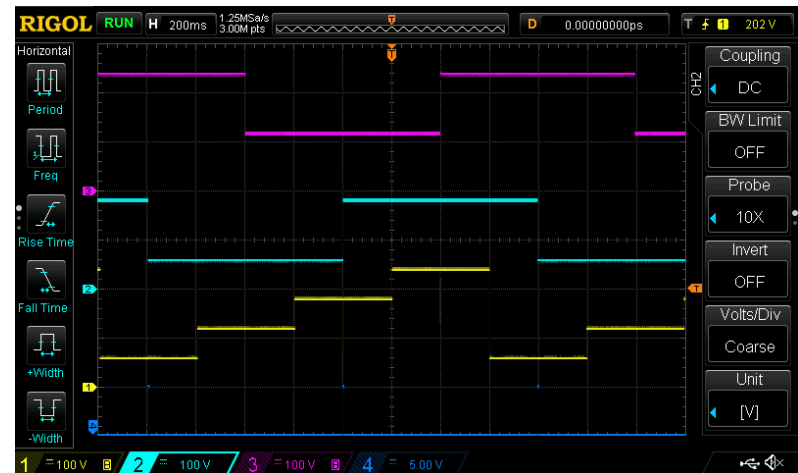
Verification

Buffer Scanned



Ch1: buffer input (50V/div)
Ch2: buffer output (50V/div)

Sample & Hold



Ch1: switch input (100V/div)
Ch2: switch 1 buffered output (100V/div)
Ch3: switch 2 buffered output (100V/div)
Ch4: switch 1 control signal (5V/div)
Switch load: 27nF

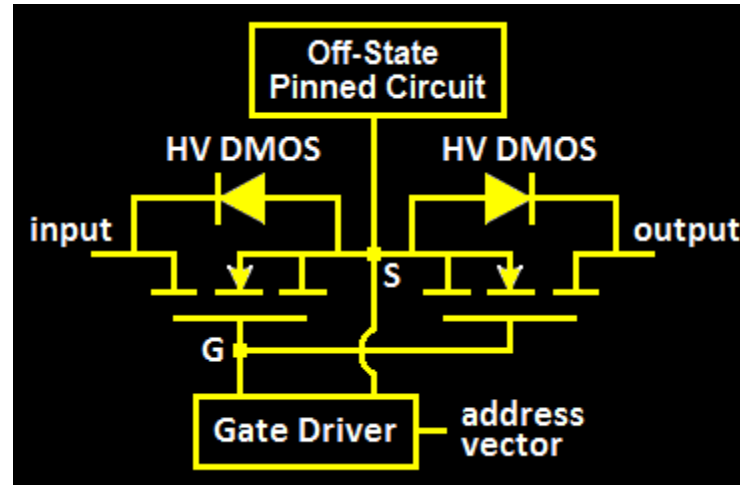
HV Transistor featuring Low Leakage & Low On-Resistance

Process Screening

- Capability for large die size (>33mmx33mm)
- The HV transistor must be high floating source or emitter
- Maximum voltage rating
- Leakage
- Current pass capability
- LV CMOS must be isolated
- MPW run option
- Radiation hardness
- Bipolar or FET
- SOI (trench isolation) or Epitaxial wafer (junction isolation)
- Schedules

Feedthrough Free Approach

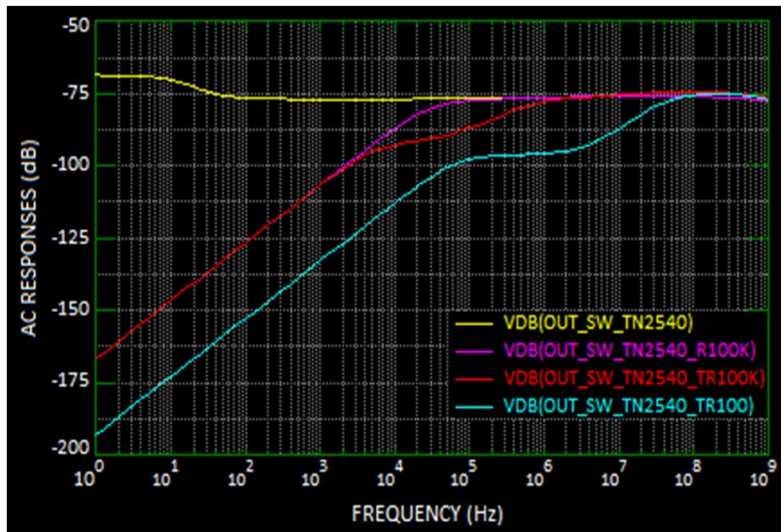
Switch with off-state pinned circuit



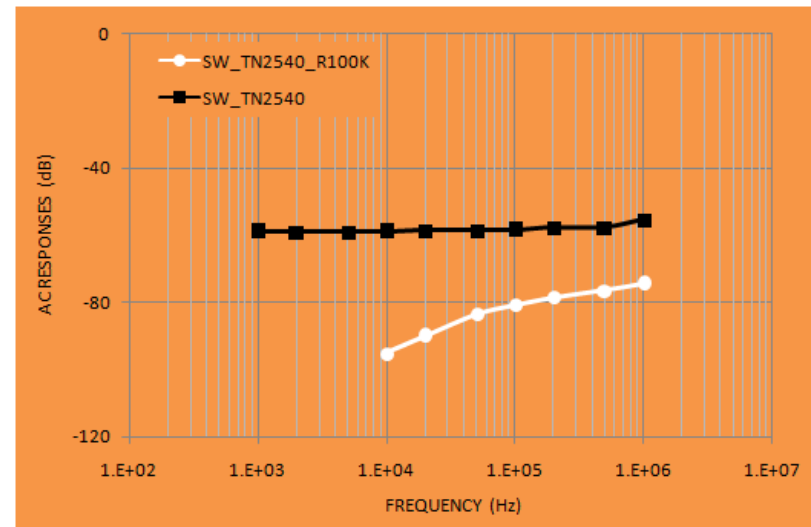
Feedthrough Free Approach-continued

Improved Isolation

Simulation Results



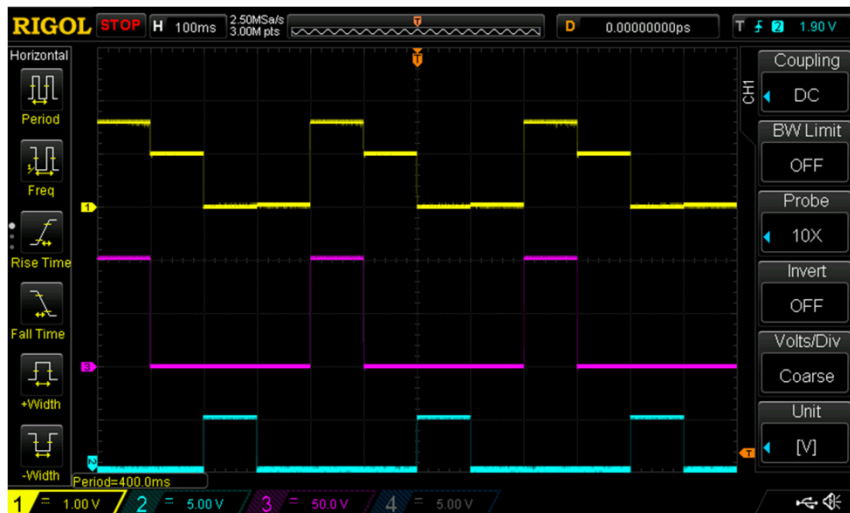
Test Results



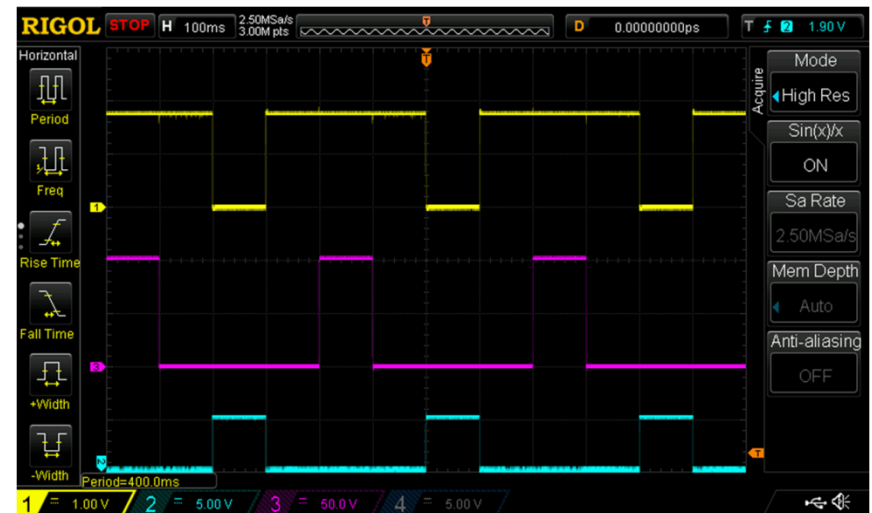
Feedthrough Free Approach-continued

Decoupled Feedthrough

Before Decoupled: SW_TP2540



Decoupled: SW_TP2540_R1M

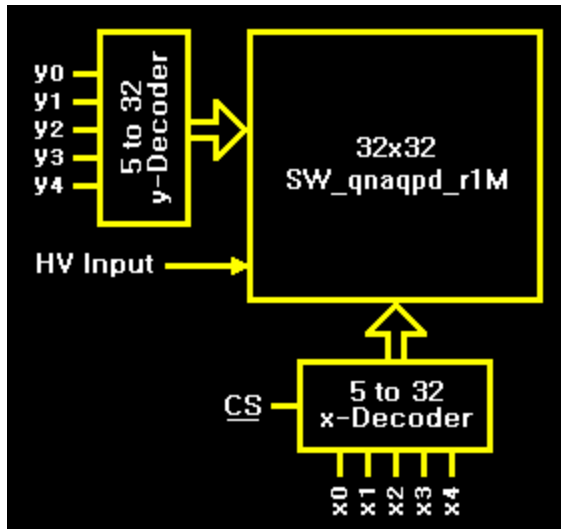


Ch1: buffered output (1V/div)
Ch2: control signal (5V/div)
Ch3: input (50V/div)

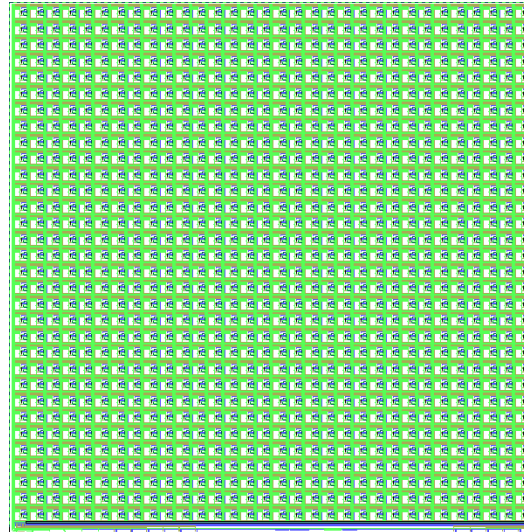
Highly Isolated 32x32 Switch Array

Device: SW1024_qnaqpd_R1M

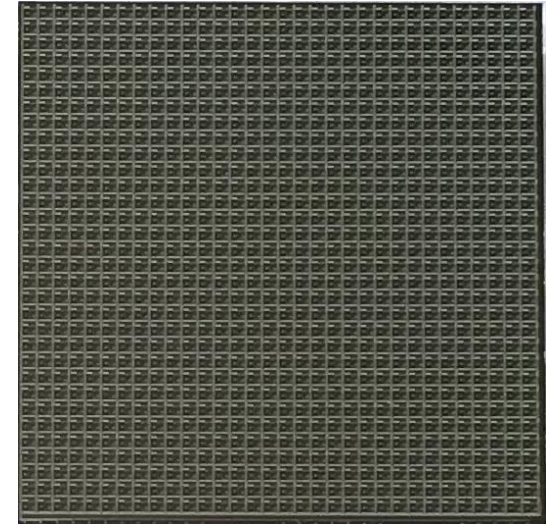
Structure



Layout



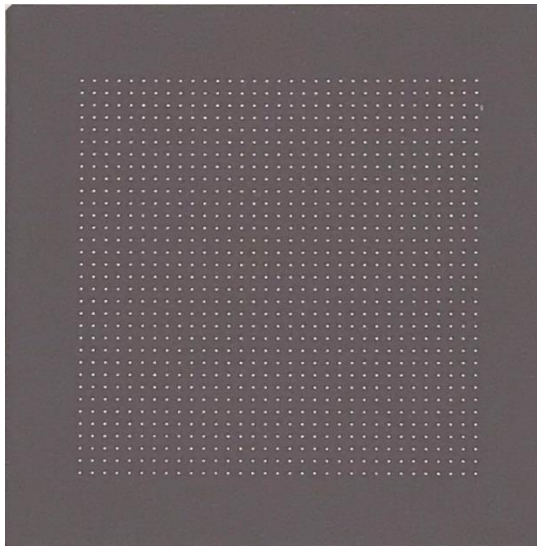
Chip (~33mmx33mm)



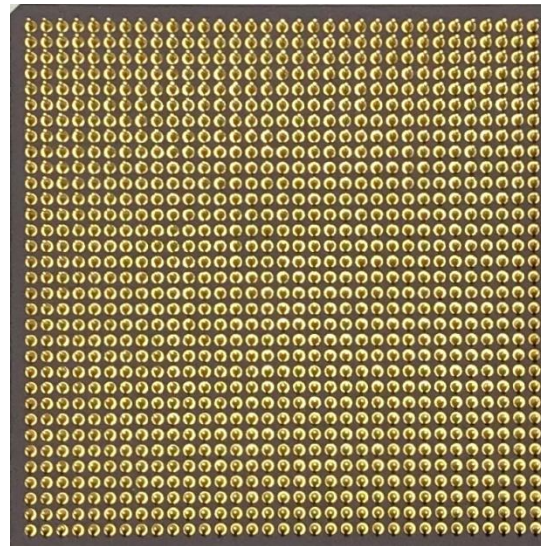
Highly Isolated 32x32 Switch Array-continued

Package

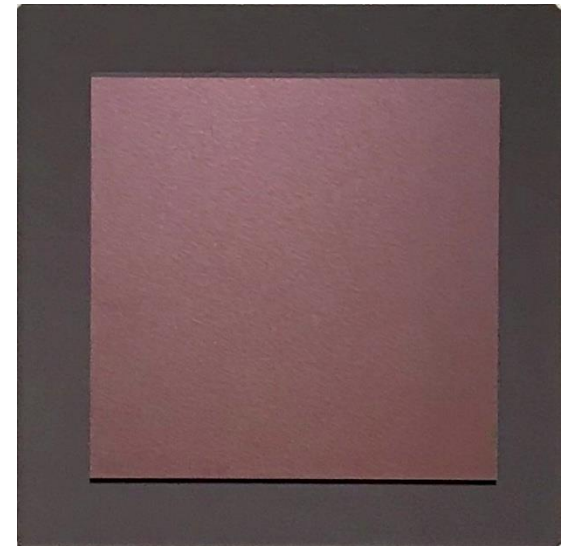
Front 33x33 FC pads



Back 33x33 pins



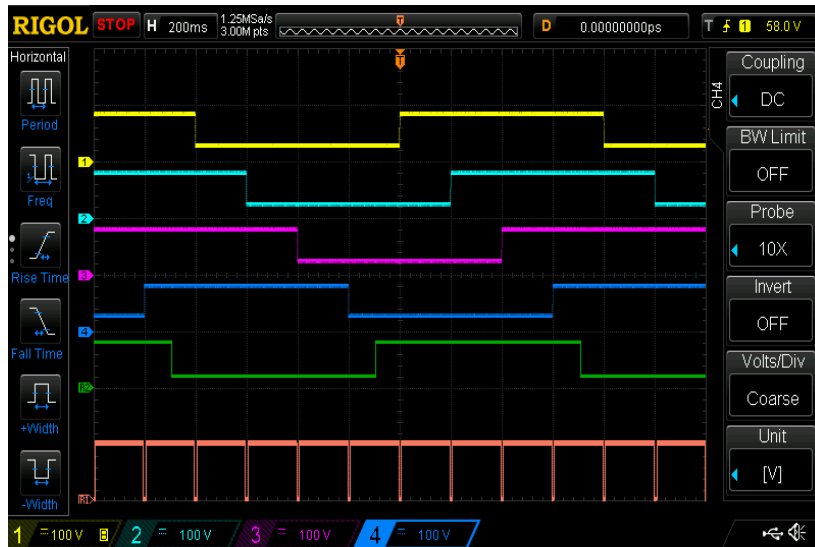
Flip chip bonded



Highly Isolated 32x32 Switch Array-continued

Some Test Results

S/H among 4 units



Channels 1 to 4: buffered outputs of S(27,29), S(20,27), S(12,31), S(5,30)
R1: chip selection bit (5V/div)
R2: analog input (100V/div)

Leakage integration $\Delta V=100V$

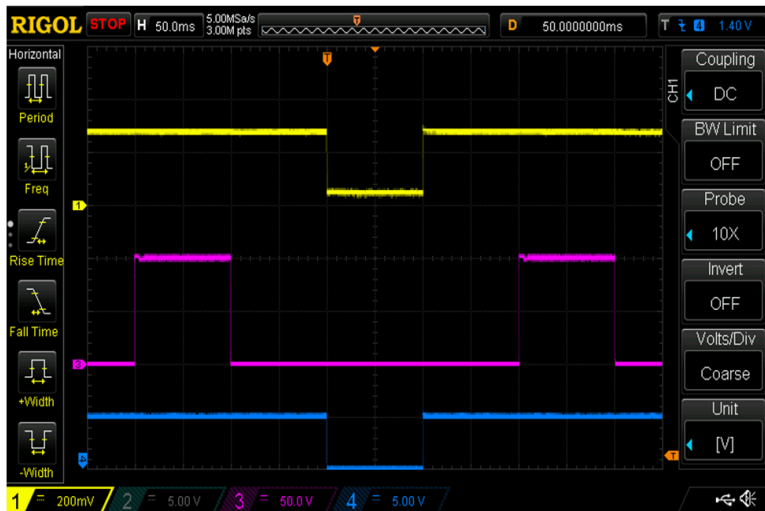


Ch1: buffered output of SW(27,29)
Ch2: buffered output of SW(20,27)
Ch3: switch input
Ch4: trigger signal

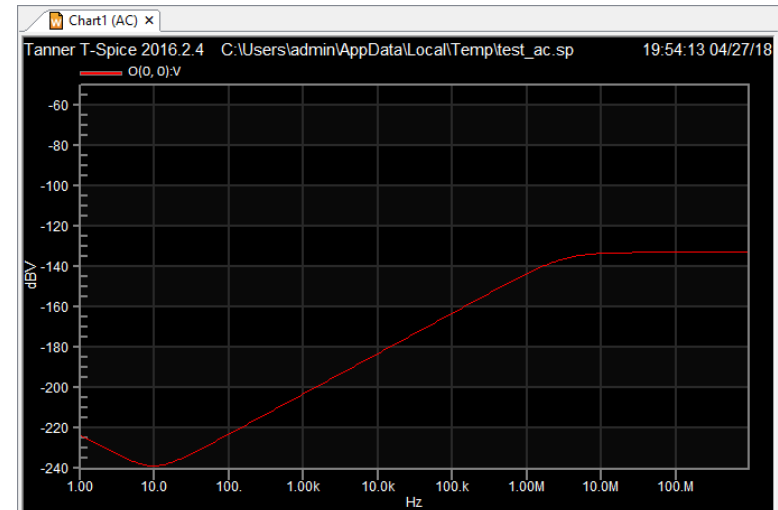
Highly Isolated 32x32 Switch Array-continued

Feedthrough & Off-Isolation

Decoupled Feedthrough



Simulated off-isolation (Cload=50nF)



Ch1: buffered output of SW(5,27)(0.2V/div) $C_o=1\text{ nF}$

Ch3: analog input (50V/div)

Ch4: chip selection bit (5V/div, active low)

Highly Isolated 32x32 Switch Array-continued

Main Specifications

parameter	value	unit
channel number	1024	
pitch	1	mm
on offset	<50	mV
small signal on-resistance ($\Delta V_{out} < 1V$)	<200	Ω
leakage	<2	pA
feedthrough (100V input change)	<40	fF
adjacent coupling (100V change)	<80	fF
voltage-resolution for 50nF loads ($0.5Hz < f < 1kHz$)	20	bit
Off-isolation ($0.5Hz < f < 1kHz$)	<-120	dB
voltage rang ($V_{pp} - V_{nn} \leq 105V$, $V_{nn} \leq 0V$, $V_{pp} \geq 10V$)	100	V
static power dissipation	<50	mW

Conclusions

By adding an off-state pinned circuit, the feedthrough of an HV analog switch can be effectively decoupled, thus greatly enhancing the off-isolation of a switch. High quality demultiplexers built based on such highly isolated switch will make low power and compact DM drivers feasible for applications in space environments



THANK YOU