RF Hot Switch Reliability of MEMS Switches

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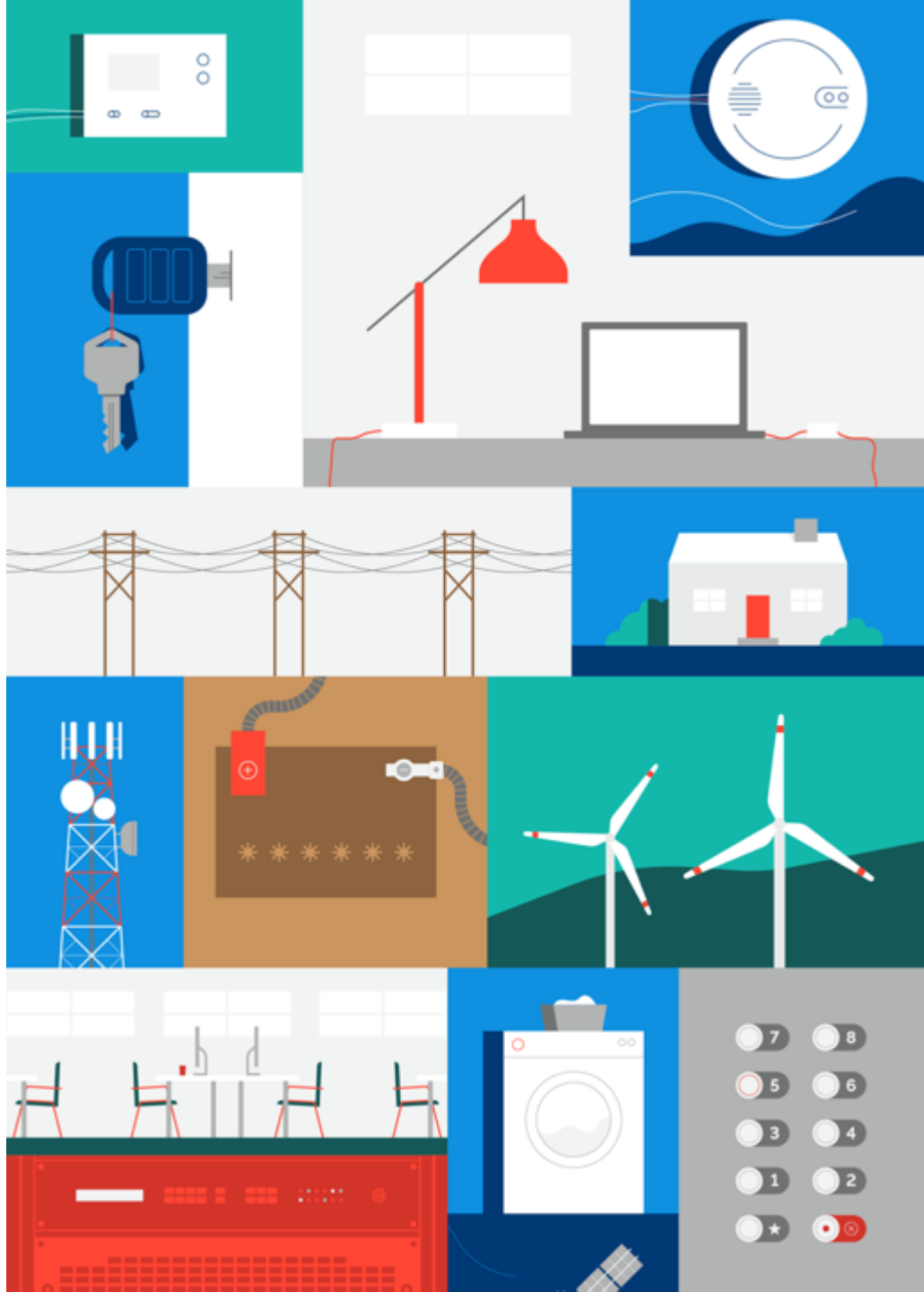
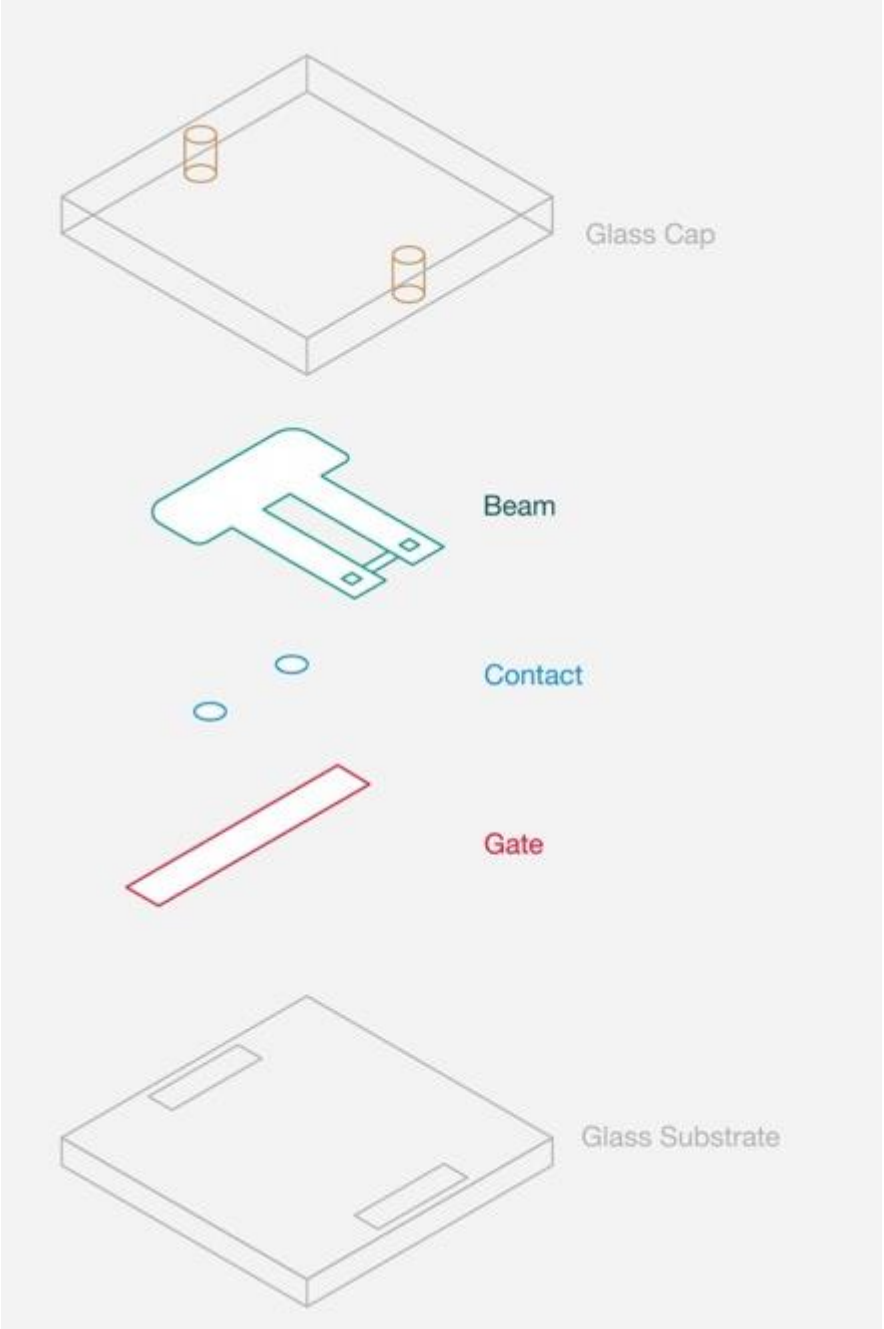


MEMS Contact Switches

- High Voltage Gate signal closes the switch
- When the gate voltage is turned on, the beam is pulled in and connects to the contact



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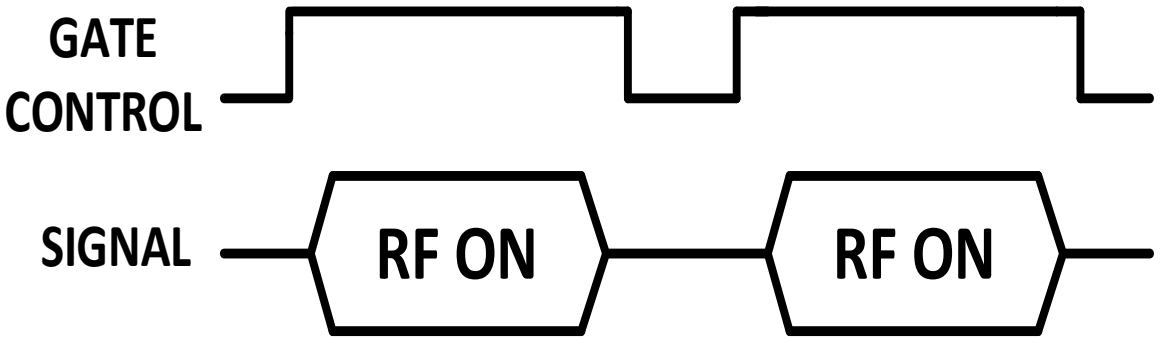
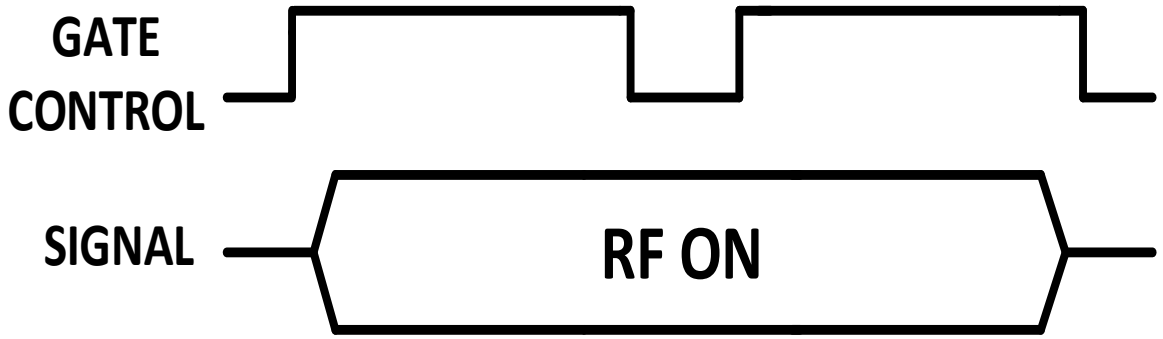
Hot Switching Introduction

- Hot Switch events occur when a switch changes state with a load signal turned on
  - For best performance, avoid hot switch events
- Hot Switch events can exacerbate failure mechanisms such as wear-out and micro-welding
- Surface materials can affect the longevity of switches
  - Using hard material as contact surface can provide resistance to wear and demonstrates capability of withstanding high-intensity arcing and to be free from sticking or pitting
  - Hard material coated in Gold (Au) on the MEMS switch contacts can extend the life

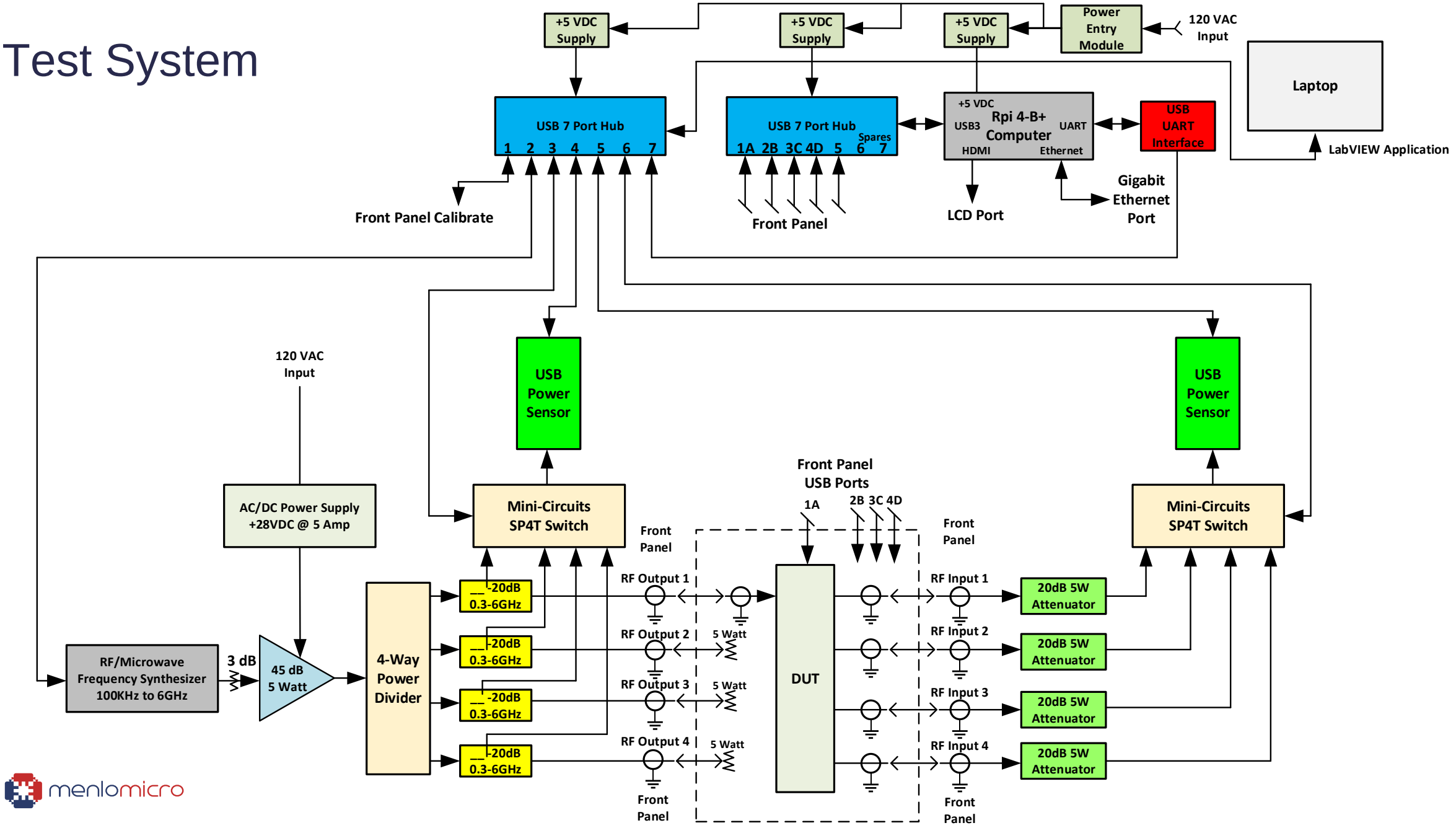


Avoids Hot Switch Events



Hot Switch Event

Test System



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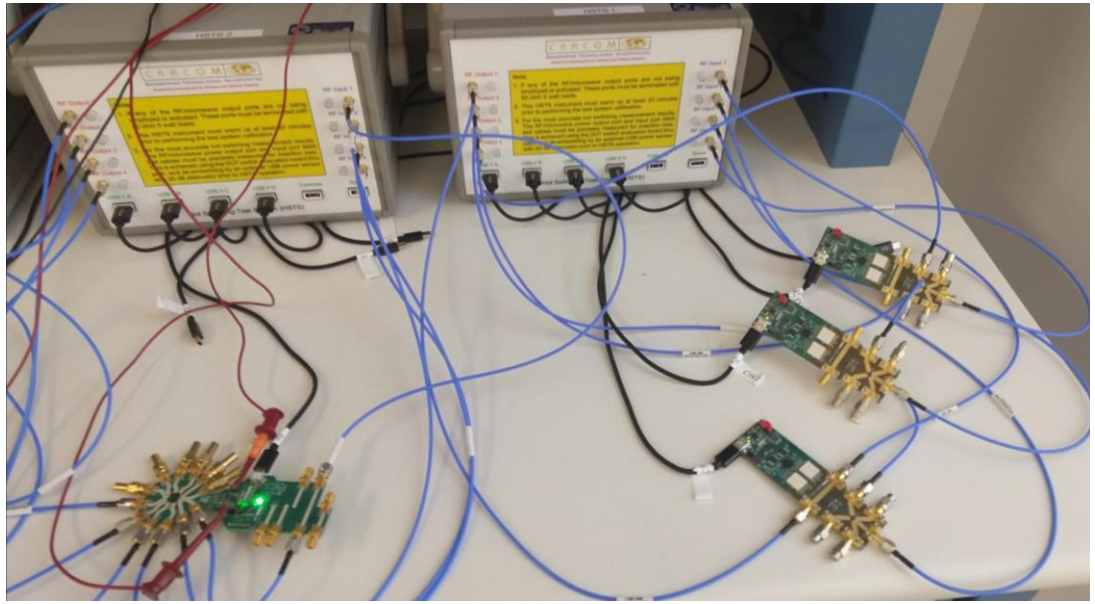
Test Methodology

- Channel under test was cycled at 10kHz
  - On State (Insertion Loss) and Off State (Isolation) measurements taken at set intervals (ex. Every 100,000 cycles)
  - All unused channels terminated with 50Ω loads
  - A thru line was also measured to ensure no anomalies in system
- 2 Failure modes:
  - “Stuck open” defined as on-state measurement indicating switch is in the off-state
  - “Stuck closed” defined as off-state measurement indicating switch is in the on-state

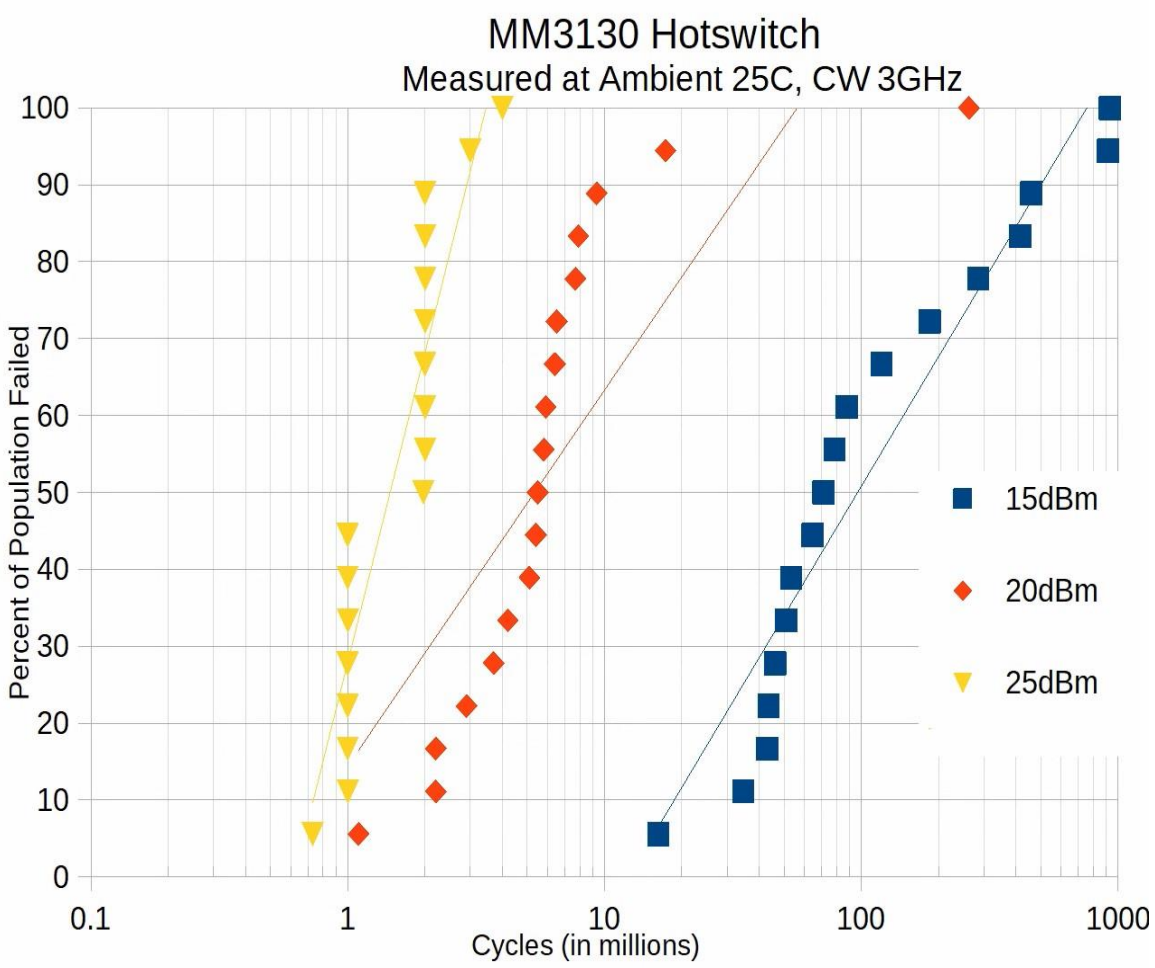


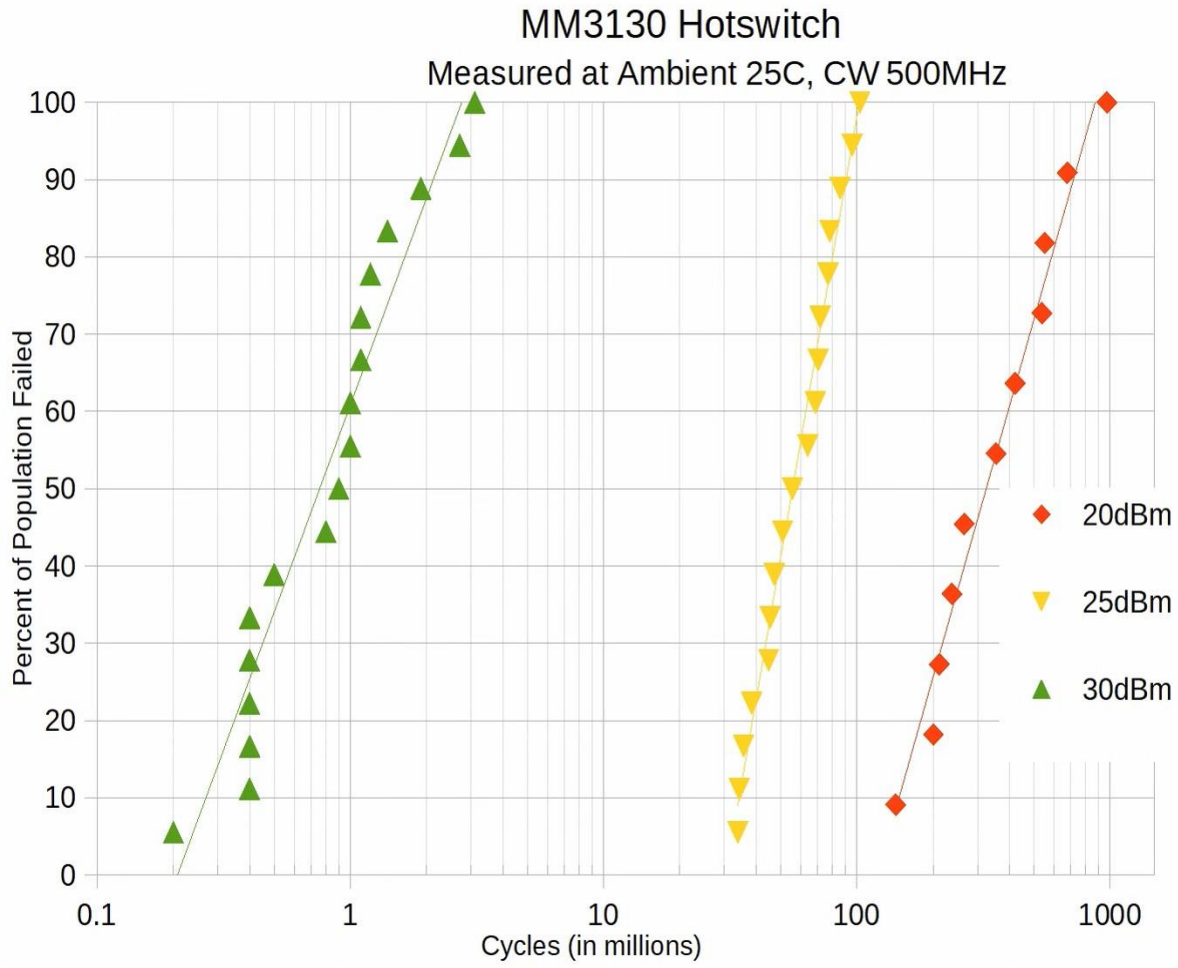
Test Conditions

- Two switch topologies tested: SP4T and SPST
- All testing was completed at room temperature

Device		**Conditions**	
Name	Topology	Frequency	Power Levels
MM3130	6 x SPST w/External Driver	500 MHz	20 dBm 25dBm 30 dBm
		3 GHz	15 dBm 20 dBm 25 dBm
MM3100	6 x SPST w/Internal Driver	500 MHz	20 dBm 25dBm 30 dBm
MM5130	SP4T	500 MHz	20 dBm 25dBm 30 dBm

MM3130 Results





- Generally, the switches failed “stuck closed”

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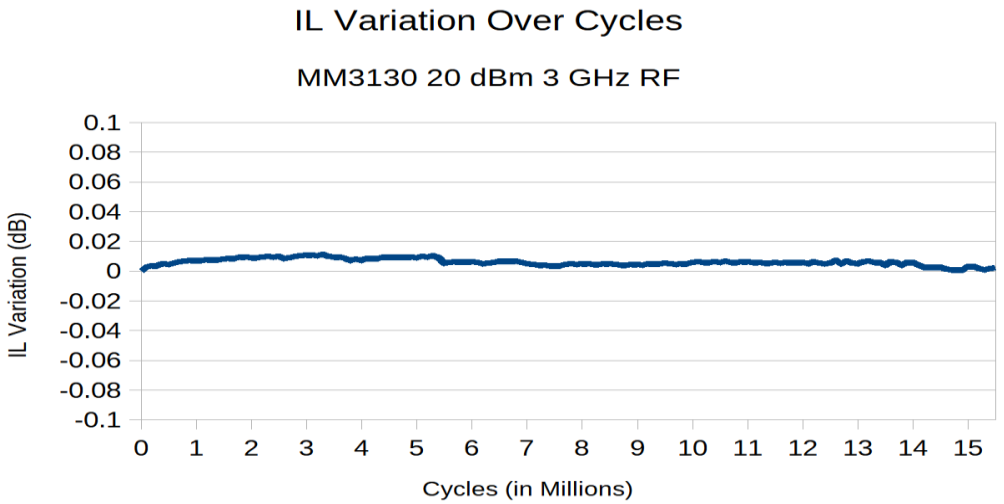
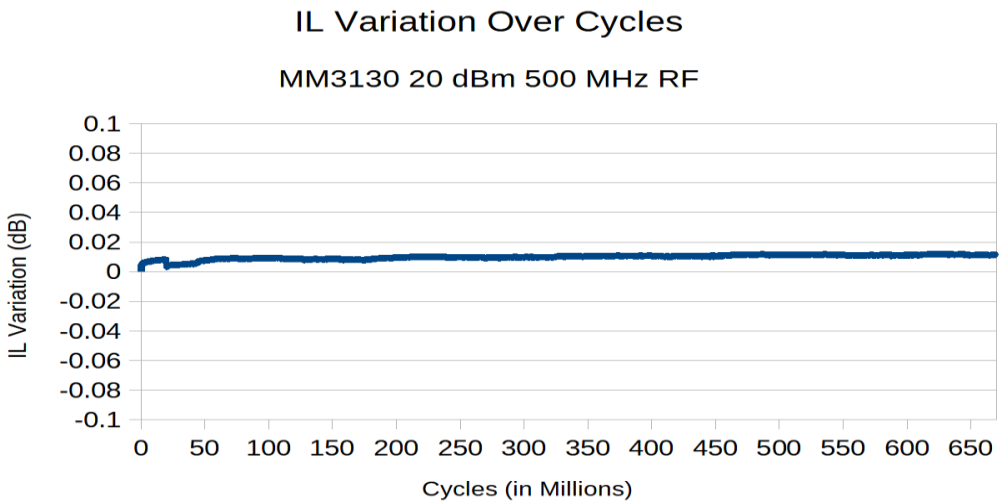
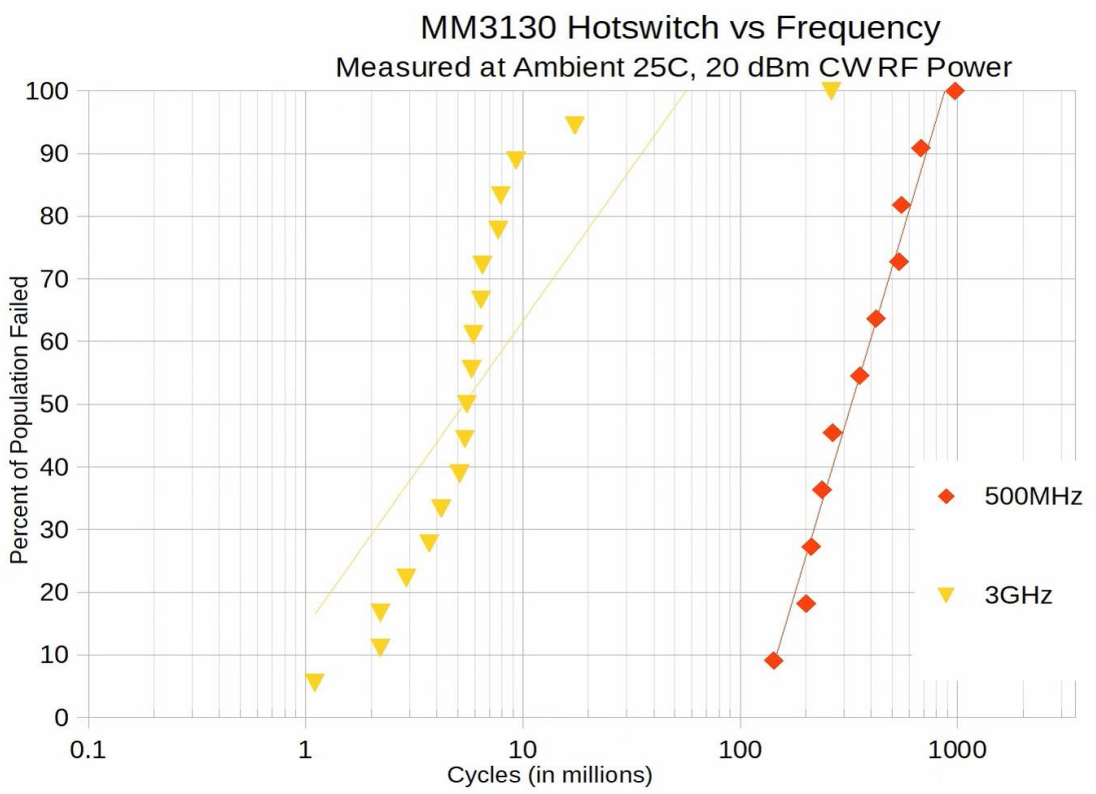
MM3130 Results (cont.)







- Insertion Loss variation was less than 0.02dB over the lifetime of the switch
- Higher frequencies has a greater impact on switch lifetime

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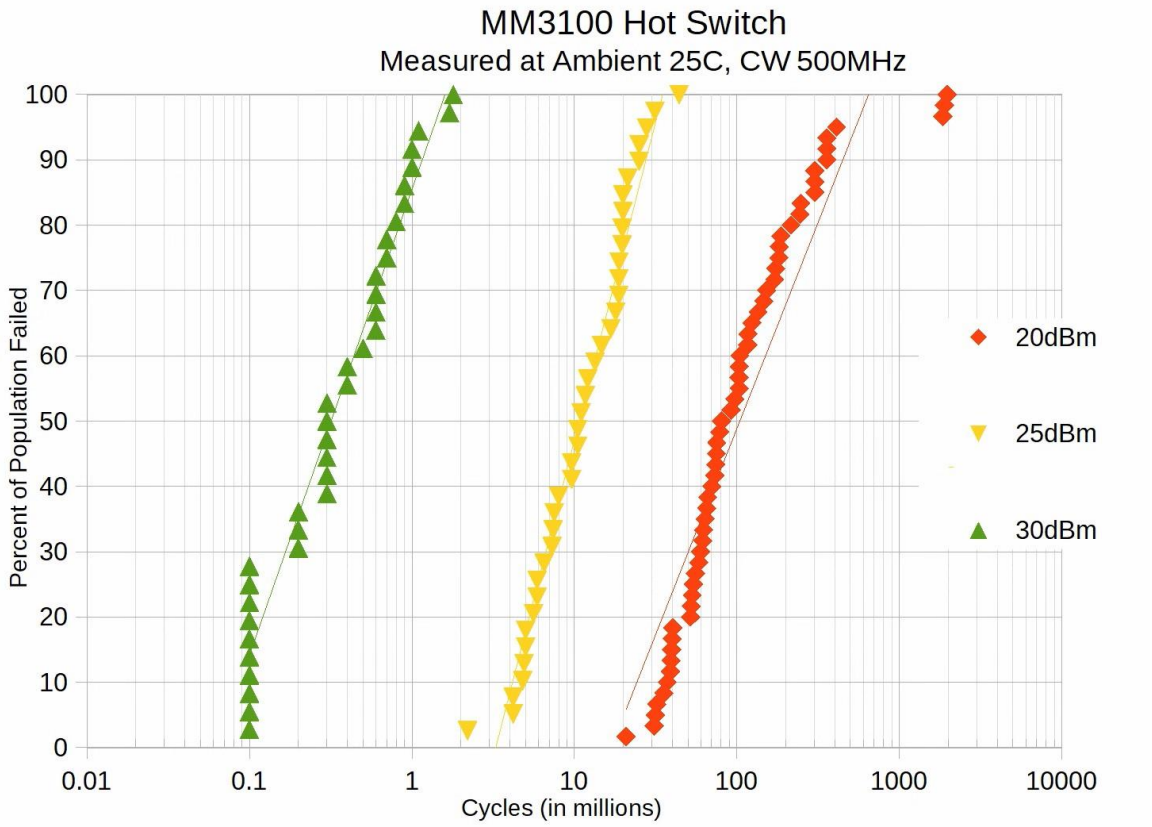
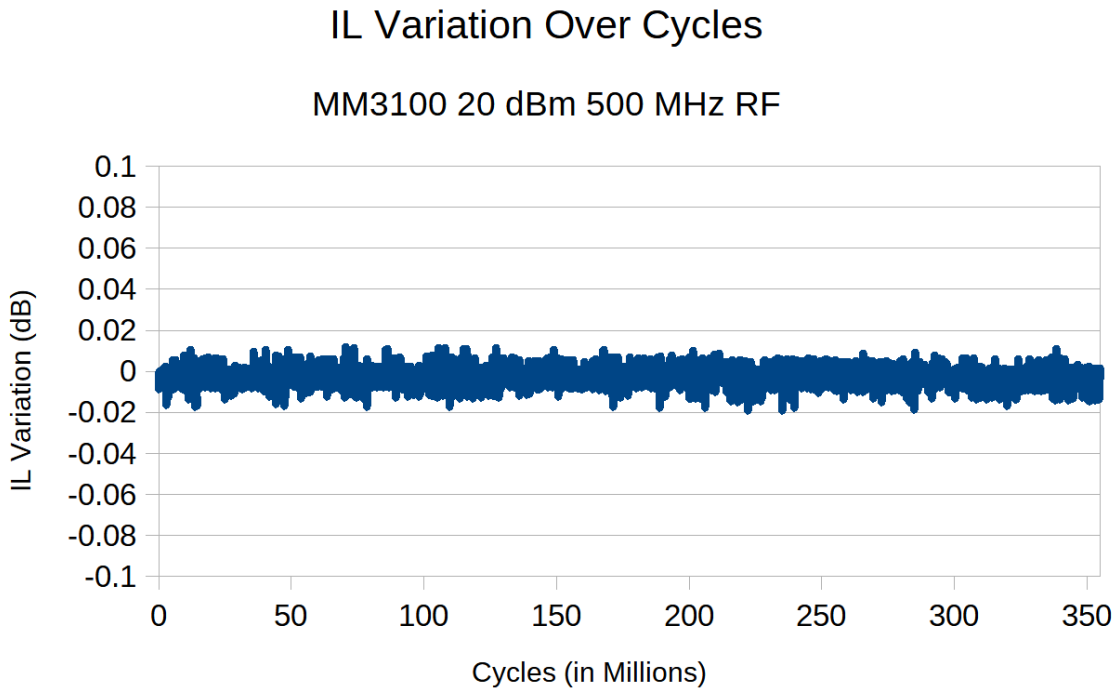
MM3100 Results





- Generally, the switches failed “stuck closed”
- Insertion Loss variation was less than 0.02dB over the lifetime of the switch

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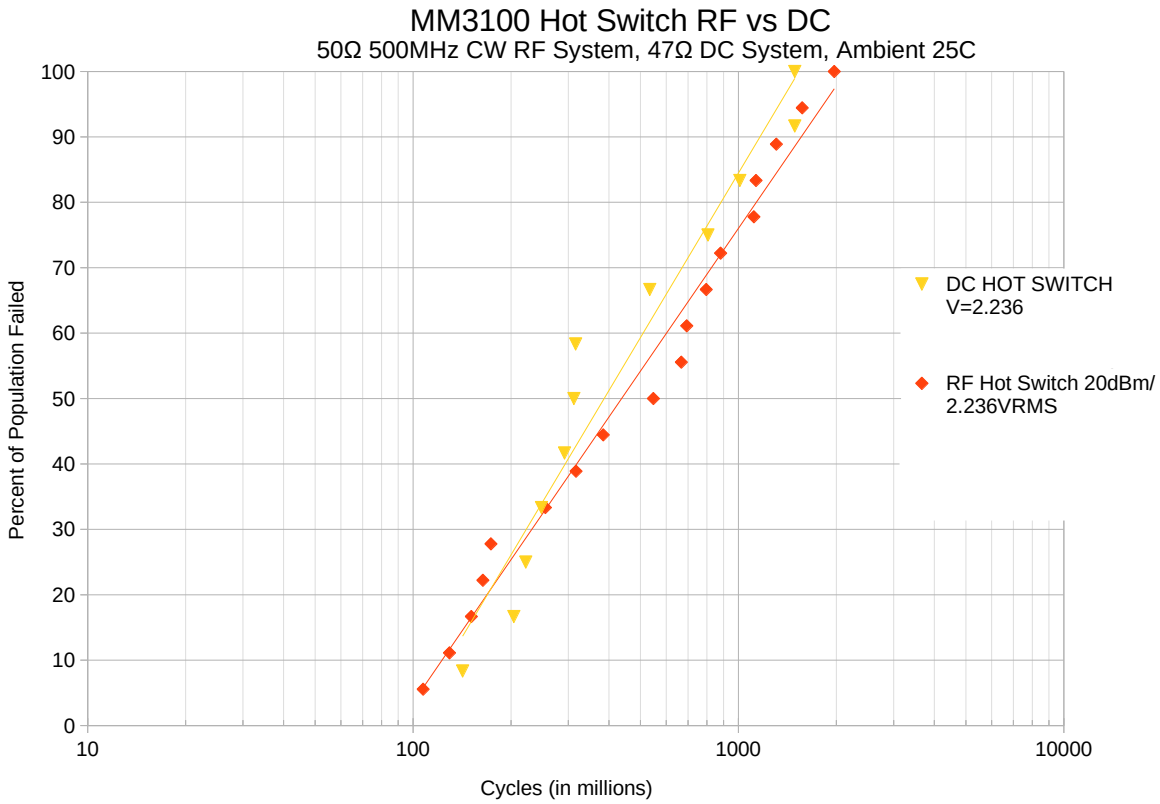
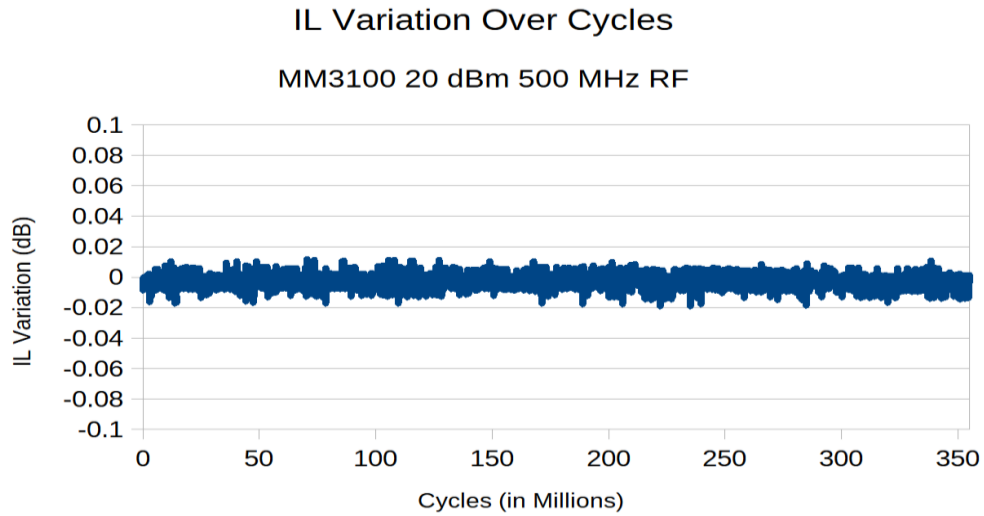
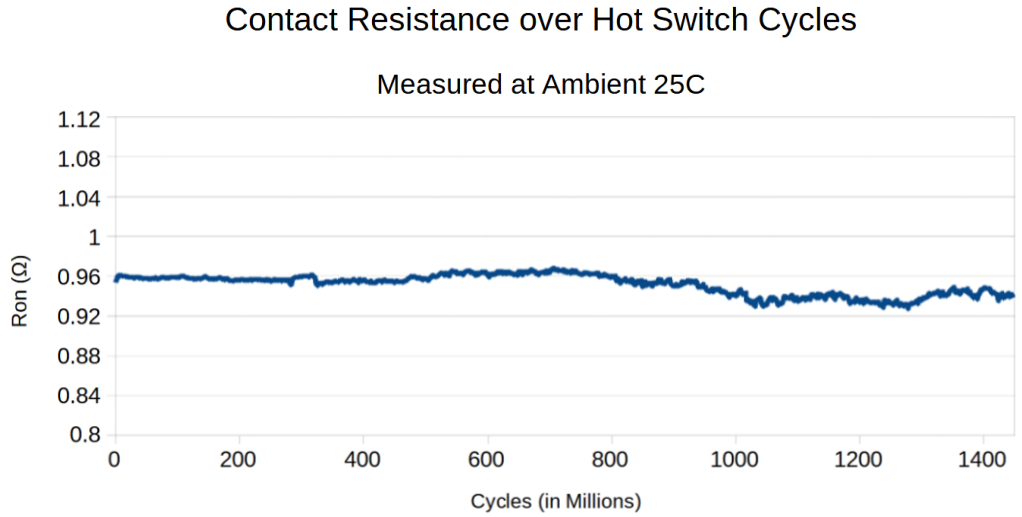
MM3100 RF vs DC Hot Switching







- RF system run at 20dBm, 50 Ω, V_{RMS}=2.24V, DC system run at 2.24V with 47Ω load
  - Insertion Loss variation was less than 0.02dB over the lifetime of the switch
  - Contact resistance varied by less than 0.05Ω over the lifetime of the switch

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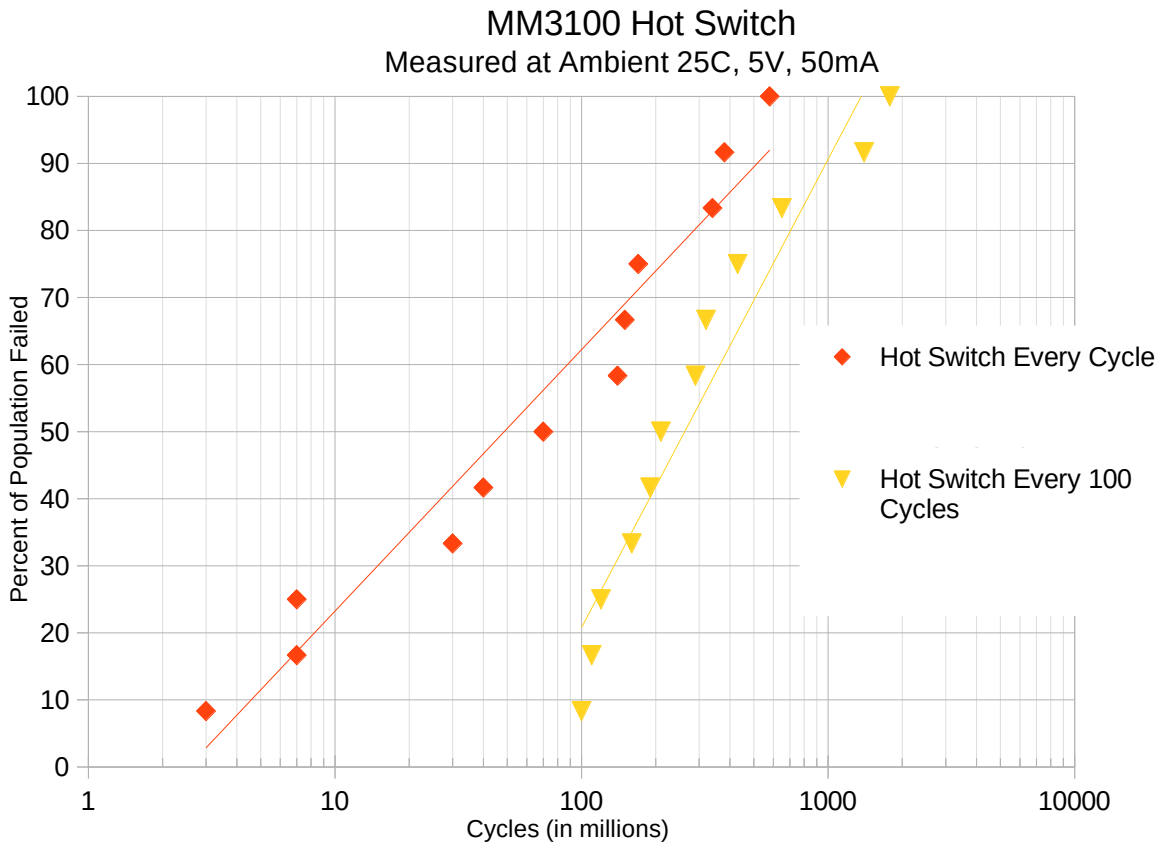
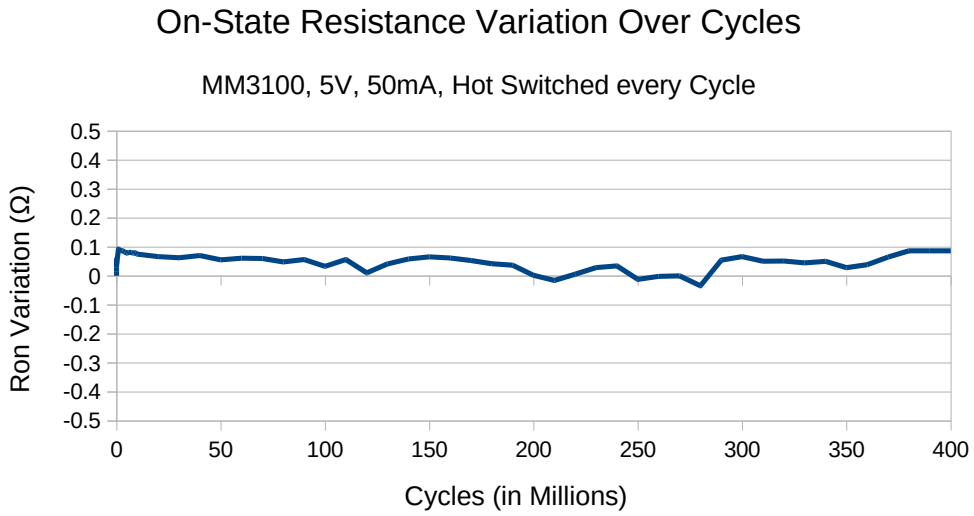
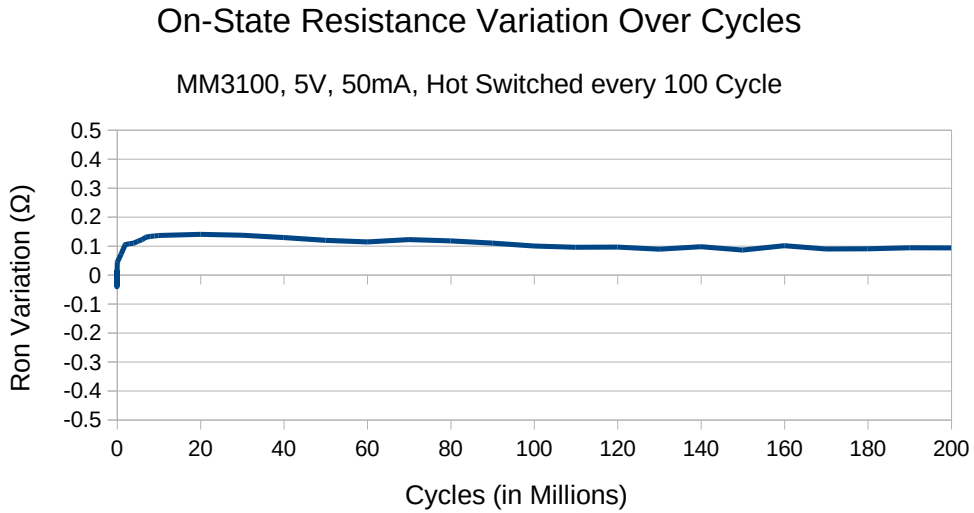
Intermittent Hot Switch Events







- Intermittent hot switch events will have less of an impact on lifetime

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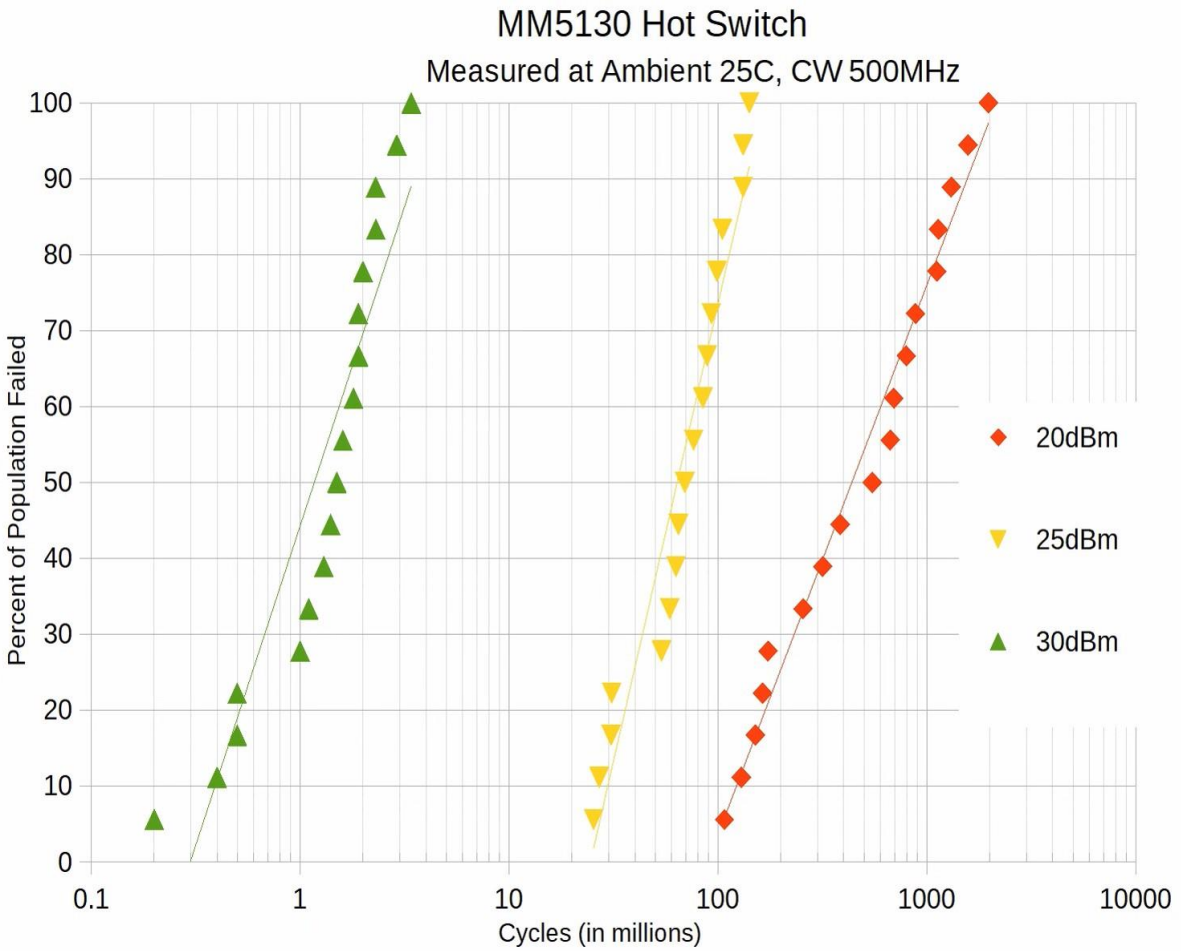
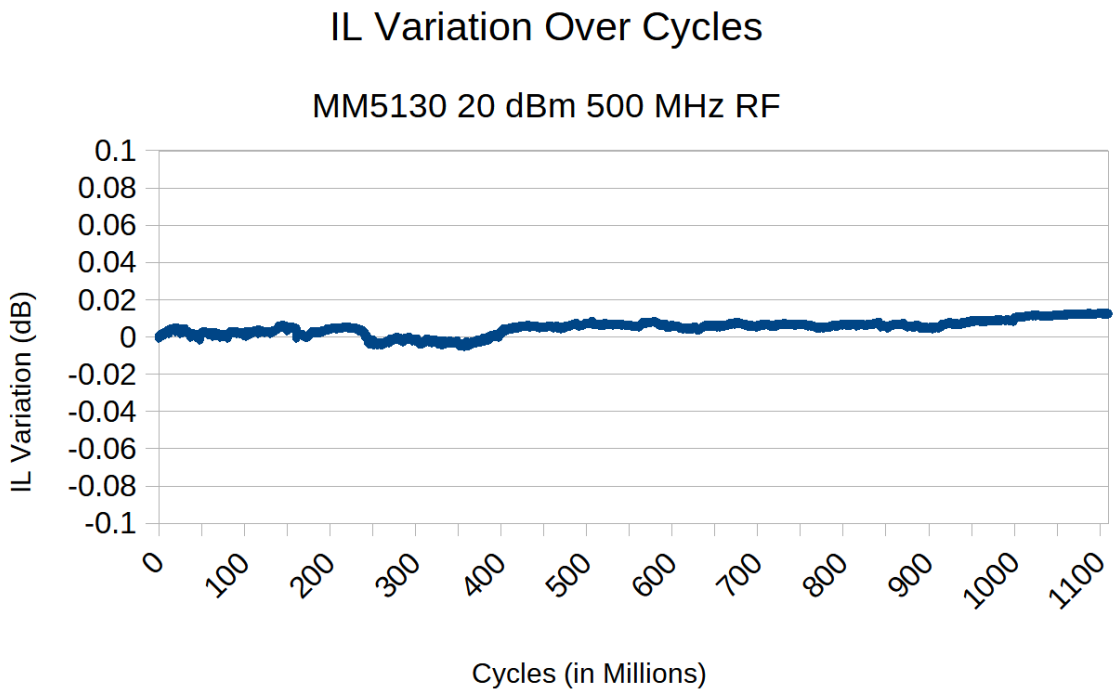
MM5130 Results





- Generally, the switches failed “stuck closed”
- Insertion Loss variation was less than 0.02dB over the lifetime of the switch

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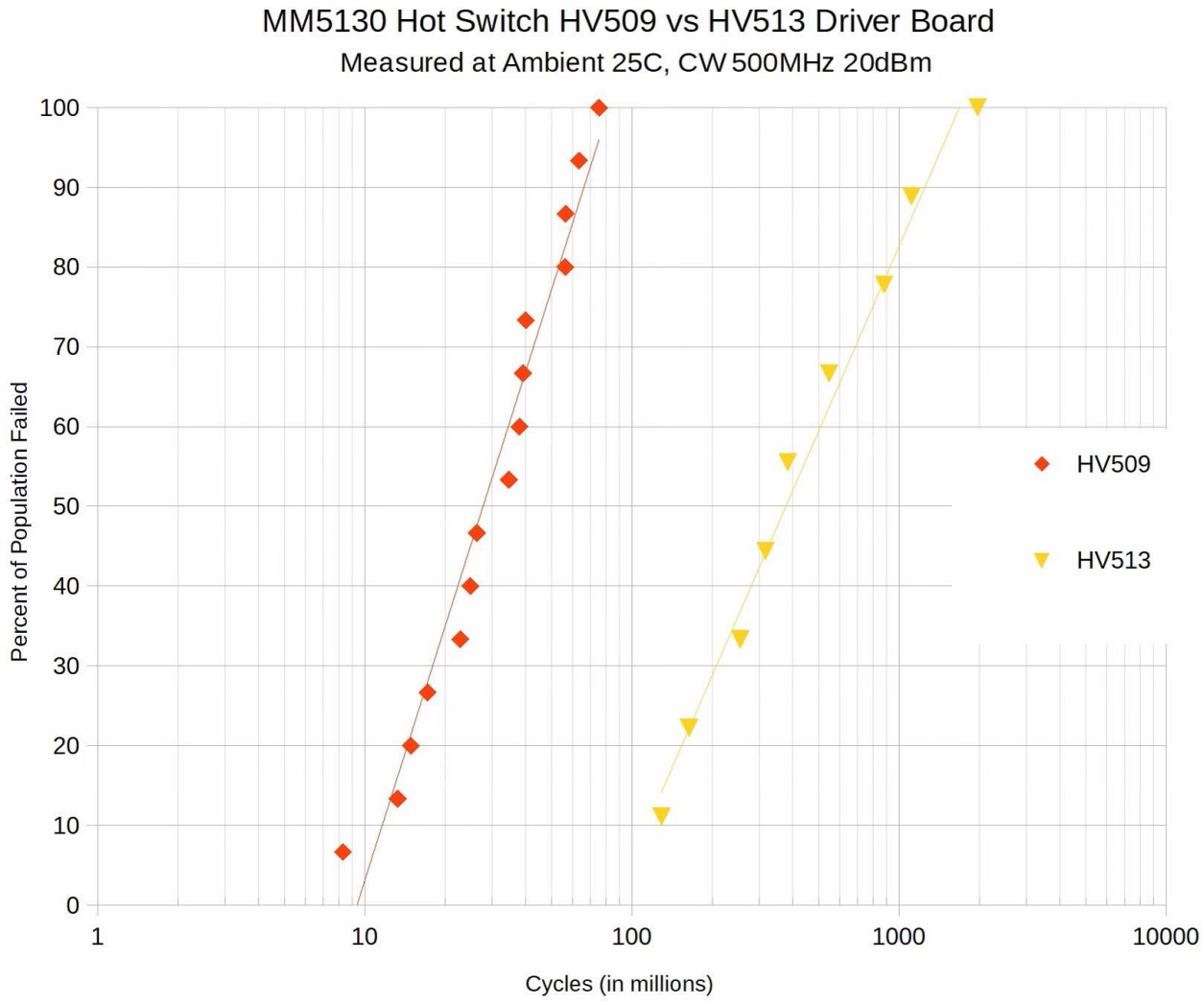
Effects of Gate Voltage Slew Rate on Life Span

Driver	Rise Time	Fall Time
HV513	2920 ns	653 ns
HV509	2171 ns	5046 ns

- The slew rate of the driver affects the hot switch lifetime of the switch
  - A quicker slew rate will result in better hot switch lifetime



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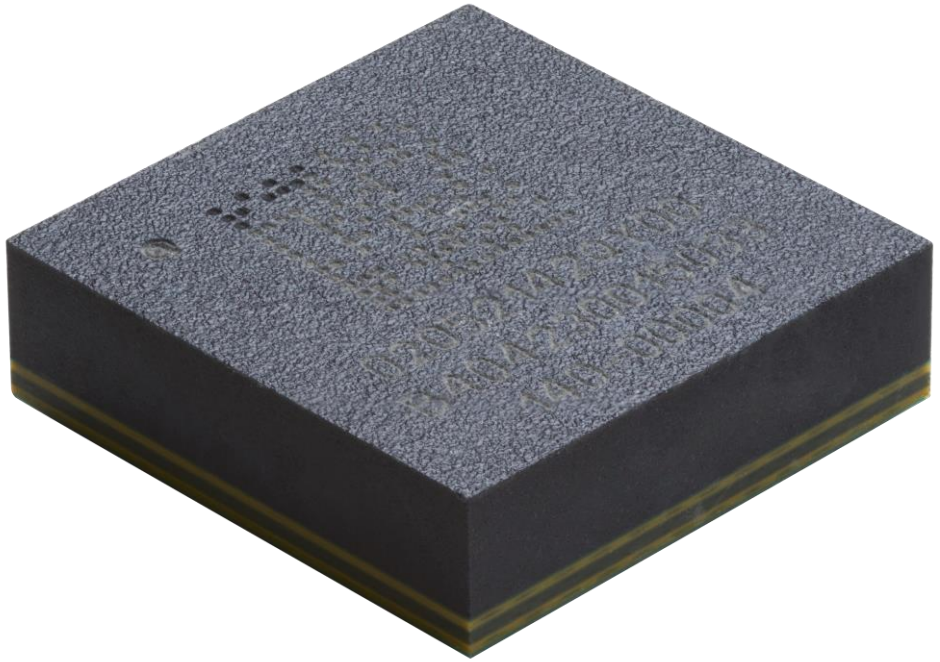
Conclusions

- Although lifetime was degraded, over 100,000 cycles was observed with 30dBm (1W) hot switch events.
- Surface materials can affect the longevity of switches
  - Using hard material as contact surface can provide resistance to wear and demonstrates capability of withstanding high-intensity arcing and to be free from sticking or pitting
  - Hard material coated in Gold (Au) on the MEMS switch contacts can extend the life
- Slew rate impacts hot switch lifetime, quicker slew rate is better for longevity
- Protection circuits can be used to mitigate hot switch events and improve switch lifetime.



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