MMFE-8 Noise Measurements at Arizona

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MM Signal

- The charge from a MIP is approximately 80 fC
  - 50e x 10e4 x 1.6e-19 x 1e15
- And is distributed over ~5 strips: 16 fC / strip
- So the output signal (MO) is
  - 48, 144, 256 mV
  - For VMM gain of 3, 9, 16 mV/fC

Intrinsic VMM Noise

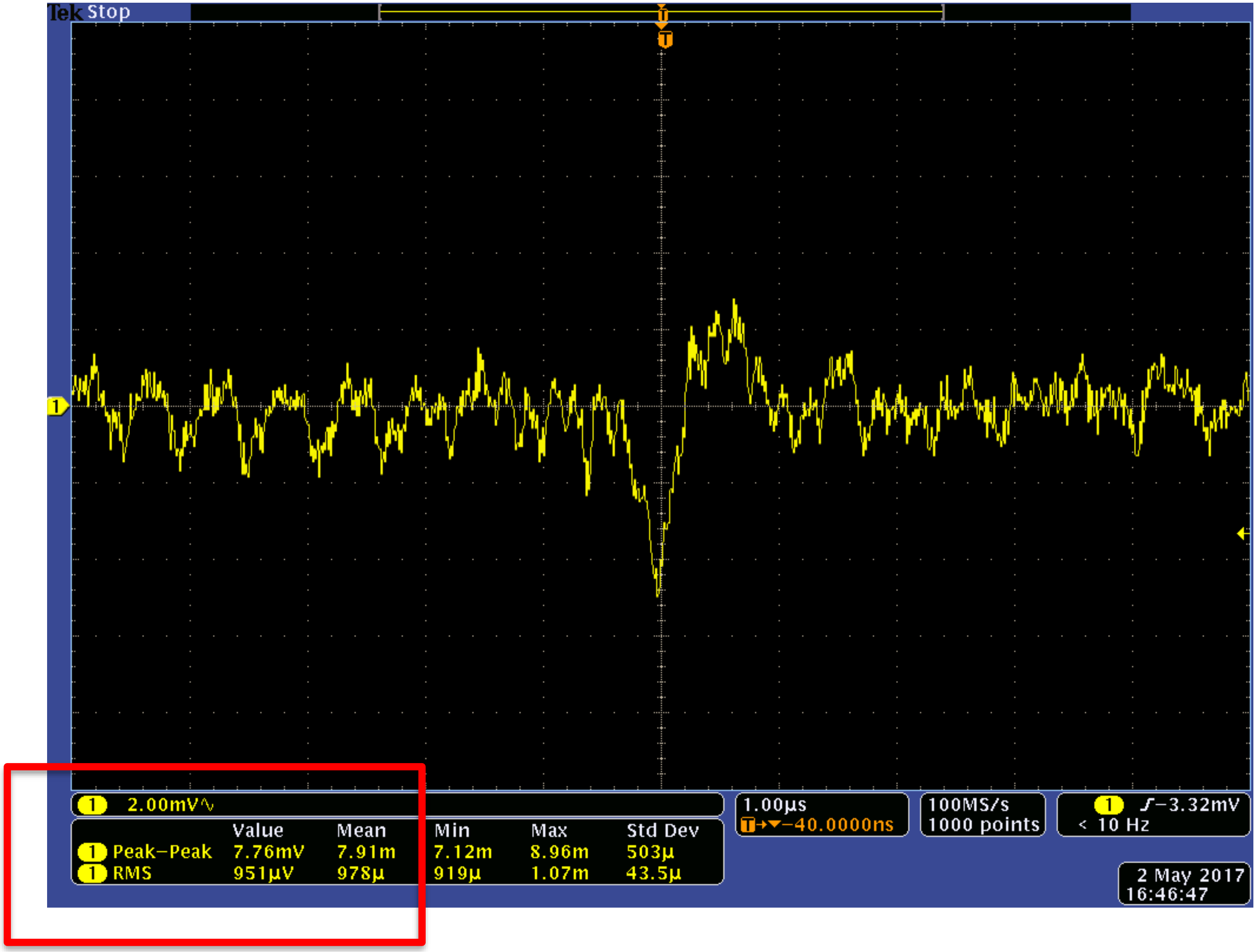
- $ENC(electrons) = (250 + 10 \cdot C_{det})\sqrt{\frac{200ns}{\tau_{peak}}}$
- For VMM parasitic capacitance of 23 pf

							3 mV/fC	9 mV/fC	16 mV/fC
	pf	ns	ns	electrons	fC		mV	mV	mV
q	cdet	tp0	tp	enc	enc		mo	mo	mo
1.60E-19	23	200	200	480	0.077		0.23	0.69	1.23
1.60E-19	23	200	100	678.82251	0.109		0.33	0.98	1.74
1.60E-19	23	200	50	960	0.154		0.46	1.38	2.46
1.60E-19	23	200	25	1357.64502	0.217		0.65	1.96	3.48

Noise Measurement Procedure

- Use MO, terminated at 1 Mohm
- Trigger scope at largest negative value where the pulse still triggers
- Initially, we recorded RMS value of MO about 5 times and average
  - More recently we record value and mean of both RMS and peak-peak values
  - Recall MO output includes both intrinsic VMM noise and DCDC ripple noise
- Sometimes we also add a 27pf or 220pf external capacitor to the channel input

Noise Measurement Procedure



Filtering

- We are constantly working to improve the filtering by appropriate choice of capacitors, inductors and their basic (SRF) properties
- Thus there is some variation, especially in early measurements, because snapshots were collected with different filtering values

Rev C

- Early bench measurements

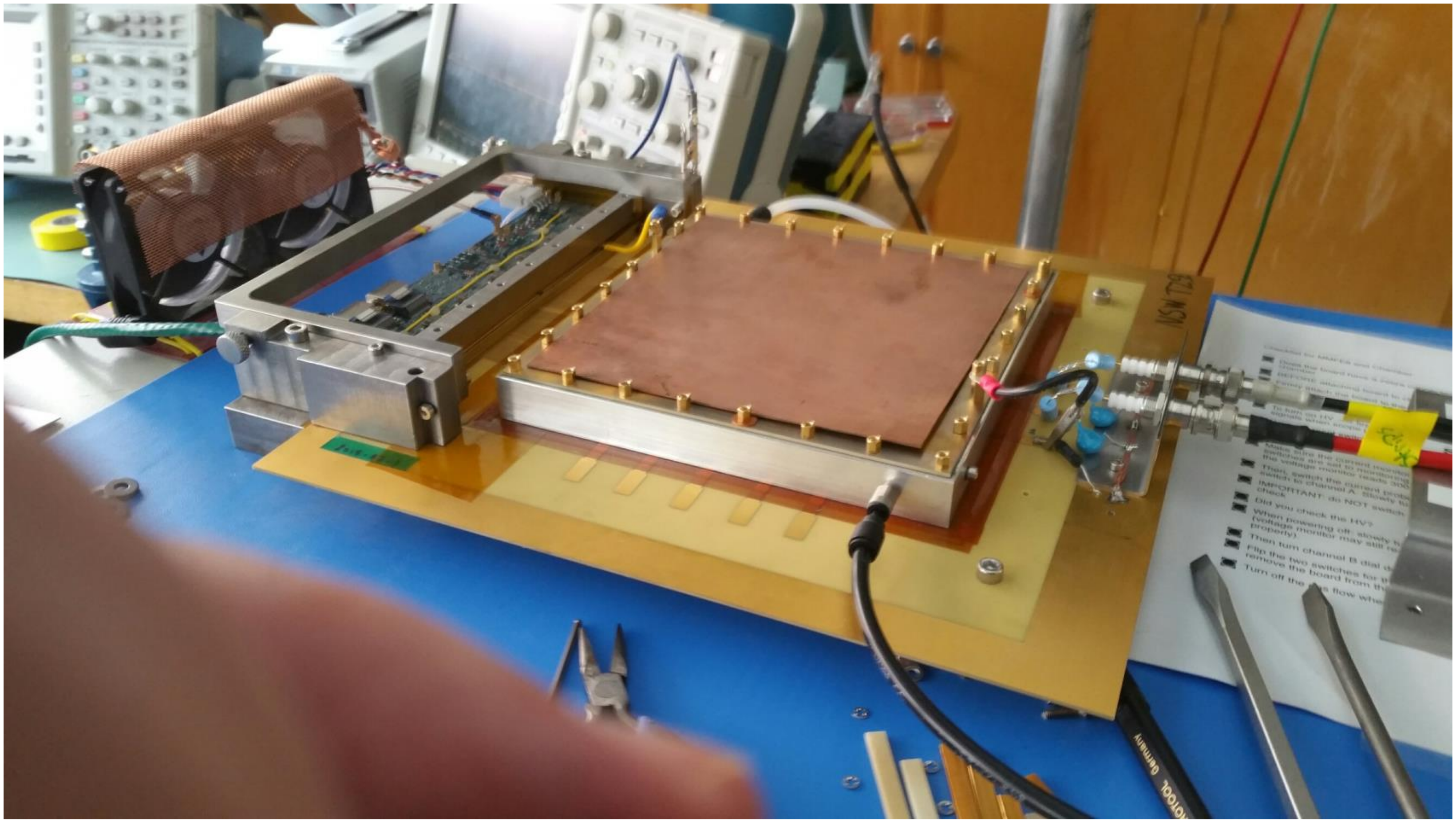
mV	pf	mV /fC	ns	mV	mV	mV	
output rms	c det	gain	peak time	output rms	vmm intrinsi	vmm ripple	ratio ripple/intrins
measured				measured	calculated	extracted	
0.29	23	3	200	0.29	0.23	0.18	0.79
0.41	50	3	200	0.41	0.36	0.19	0.53
0.46	247	3	200	0.46	1.31	#NUM!	#NUM!
0.32	23	9	200	0.32	0.69	#NUM!	#NUM!
0.38	50	9	200	0.38	1.08	#NUM!	#NUM!
1.69	247	9	200	1.69	3.92	#NUM!	#NUM!
0.32	23	16	200	0.32	1.23	#NUM!	#NUM!
0.43	50	16	200	0.43	1.92	#NUM!	#NUM!
3.51	247	16	200	3.51	6.96	#NUM!	#NUM!
0.32	23	9	200	0.32	0.69	#NUM!	#NUM!
0.38	50	9	200	0.38	1.08	#NUM!	#NUM!
1.69	243	9	200	1.69	3.92	#NUM!	#NUM!

FEAST + VMM2

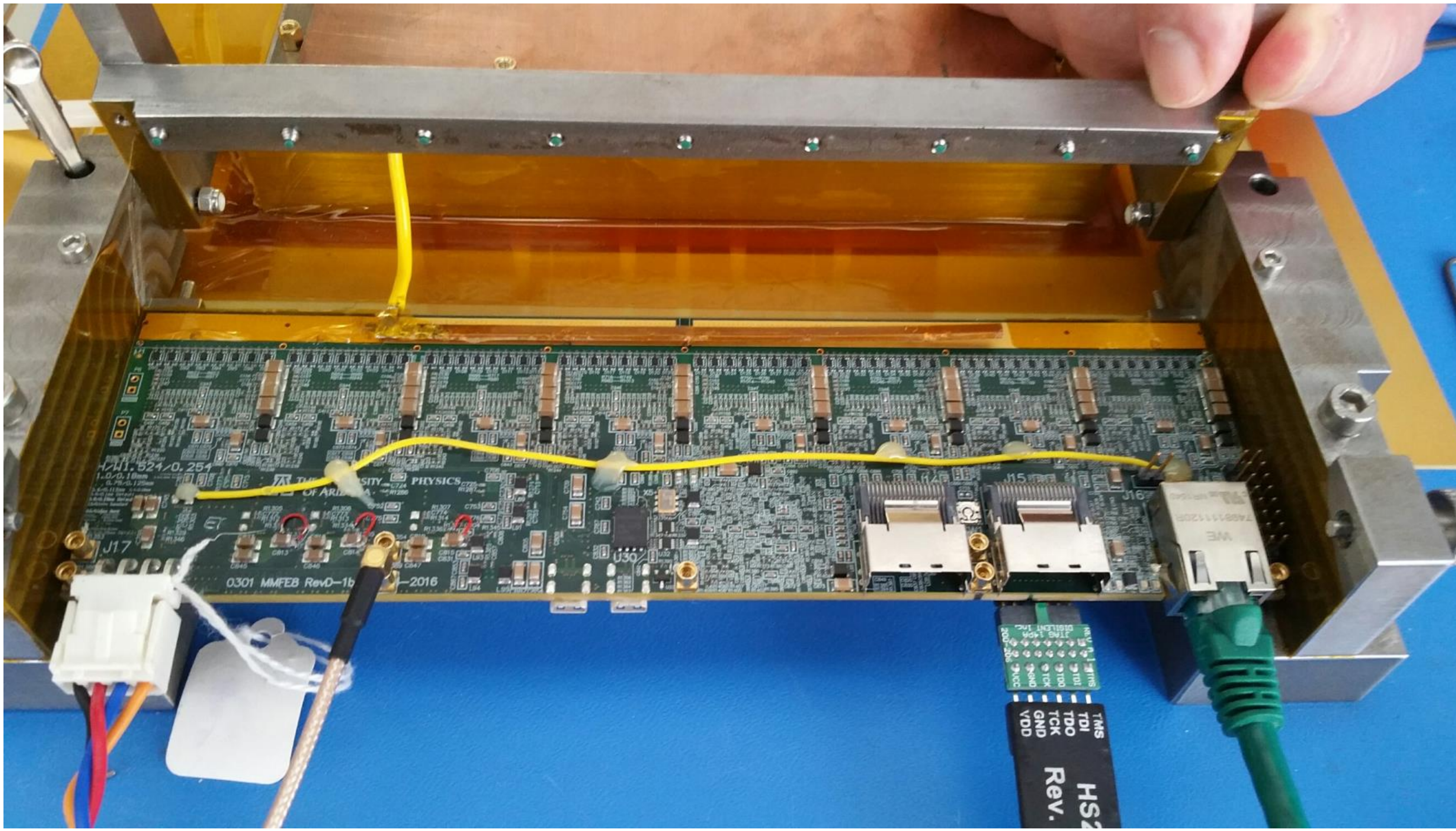
- Bench

3/7/2017 vmm2+feast				same as col a				
mo				mo				
mV	pf	mV /fC	ns	mV	mV	mV		
output rms	c det	gain	peak time	output rms	vmm intrinsi	vmm ripple	ratio ripple/intrinsi	
measured				measured	calculated	extracted		
0.37	23	3	200	0.37	0.23	0.29	1.28	v
0.40	50	3	200	0.40	0.36	0.18	0.50	v
1.28	243	3	200	1.28	1.29	#NUM!	#NUM!	v
0.85	23	9	200	0.85	0.69	0.50	0.72	v
1.12	50	9	200	1.12	1.08	0.30	0.27	v
3.09	243	9	200	3.09	3.86	#NUM!	#NUM!	v
1.54	23	16	200	1.54	1.23	0.93	0.76	v
1.67	50	16	200	1.67	1.92	#NUM!	#NUM!	v
5.38	243	16	200	5.38	6.86	#NUM!	#NUM!	v

AZ MM Test Chamber



AZ MM Test Chamber



FEAST + VMM2

- Bench and MM Test Chamber (AZ)

3/xx/2017	vmm2+feast			same as col a				
mo				mo				
mV	pf	mV /fC	ns	mV	mV	mV		
output rms	c det	gain	peak time	output rms	vmm intrinsi	vmm ripple	ratio ripple/intrinsic	
measured				measured	calculated	extracted		
0.29	23	3	200	0.29	0.23	0.18	0.78	bench
0.42	23	9	200	0.42	0.69	#NUM!	#NUM!	bench
0.62	23	16	200	0.62	1.23	#NUM!	#NUM!	bench
0.84	50	3	200	0.84	0.36	0.76	2.11	mm test
2.28	50	9	200	2.28	1.08	2.01	1.86	mm test
3.81	50	16	200	3.81	1.92	3.29	1.71	mm test

FEAST + VMM3

- See Ryan's talk

Conclusions

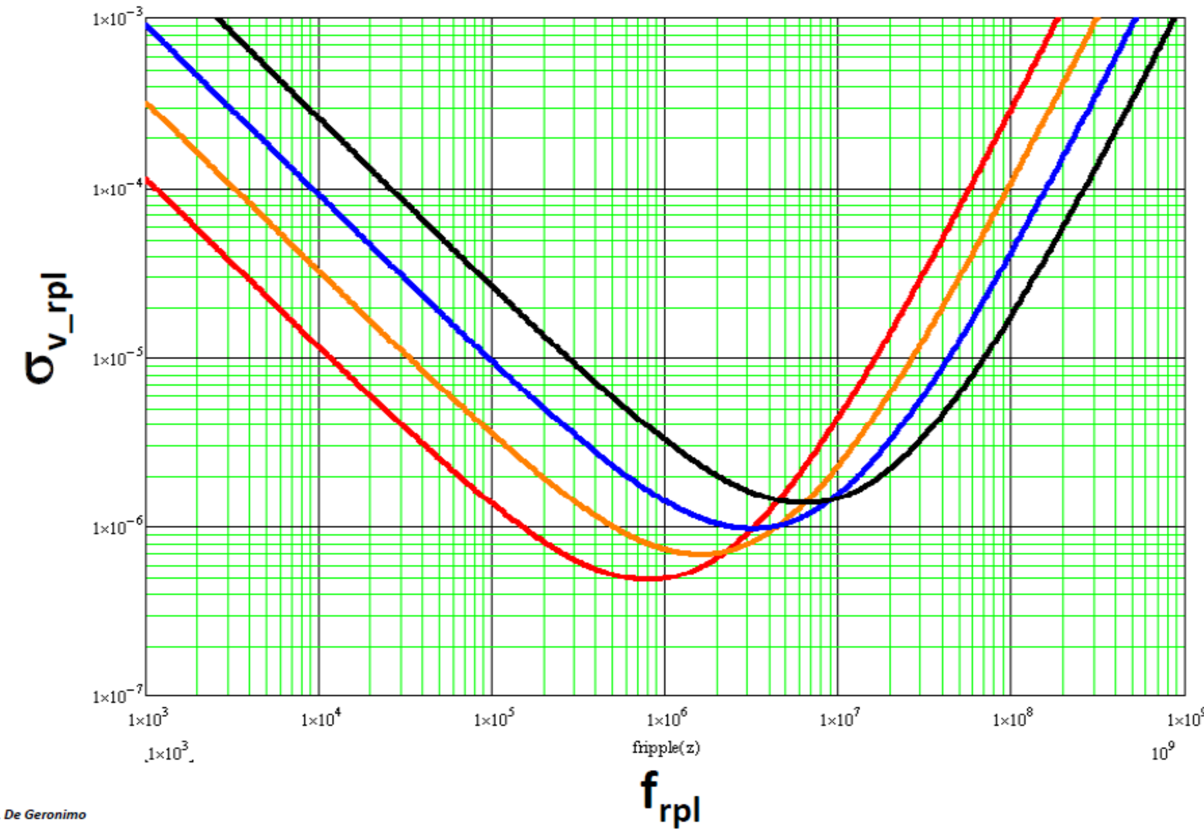
- For all boards (RevC, VMM2+Feast, VMM3 Feast), bench measurements of the MMFE8 noise as measured as MO are approximately the level of the intrinsic noise
- Using the AZ MM test chamber and VMM2+FEAST board shows MMFE noise about a factor of 2 times the intrinsic noise
- Not presented, but there is consistency between noise measurements made using the MO and those from XADC data
- Additional noise suppression can be accomplished by continued optimization of the filtering capacitors

Backup

Power Noise Goal

- Keep ENC ripple close to intrinsic ENC
- Roughly < 10 uV at vddp

Maximum tolerable σ_{v_rpl} vs frequency for VMM at different peaking times (200ns, 100ns, 50ns, 25ns)



G. De Geronimo

Measurements Made

- Rev C (VMM2 + COTS DCDC + LDO)
  - Repeated measurements as done at BNL (baseline)
  - Measurements taken on test MM chamber
  - Measurements taken with shield both on and off using MM chamber
  - Measurements taken with improved pi filters (additional C on either side of pi filters)
  - Measurements taken using external lab supplies to power a Rev C board
  - Measurements taken using one Rev C board to power another Rev C board
  - Measurements with different input C

Measurements Made

- Feast V1 (VMM2 + FEAST + no LDO)
  - Baseline measurements
  - Measurements with improved pi filter
  - Measurements with external power
  - Measurements with different input C

Rev C/Rev D

- Noise Filter Design
  - A Low noise LT8612 DCDC, ripple < 10mV
    - 60 = 20 log(0.00001/0.01)
  - A Low noise LDO ADP1755, ripple < 23uV RMS, PSRR > 54db @100KHz
    - 7 = 20 log(0.00001/0.000023)
  - A series of 2nd order LPF's, (PI filters) 12db / octave, 40db / decade
    - First LPF @32KHz (320KHz = 40db), (640KHz = 52db), (1.28 MHz = 64db)
    - Second LPF @18KHz (180KHz = 40db), (680KHz = 64db), (1.36MHz = 76db)
    - All calculated to yield the desired 10uV ripple
    - Verified by simulation

Changes to Rev D

- Minimal changes from Rev C
  - 14 -> 16 layer stack, 8 power / ground planes
  - Standard BOM configures as un-optimized DCDC configuration
  - Power design abandoned since it failed radiation tests
  - ADGnd inductors replaced with 0 ohm resistor due to large power oscillations
  - Modified clock, mode, sync, and power inductor to reduce noise from 350mV -> 50-100mV
  - Verified noise due to DCDC converter as noise signature follows clock speed changes
  - Added wire to fix VMM power droop on VMM's 6, 7, 8

Changes to VMM2 + FEAST

- 14 -> 16 layer stack, 8 power / ground planes
- Analog / AD / Digital power and ground planes aligned
- Caps added to all power rails
- DCDC's and output coil's re-located away from VMM's
- Error caused failure of Isolated grounds and shields implemented for DCDC and output coils
- MO re-routed over AGND not [digital]GND
- DCDC configuration modified slightly to compensate for power droop
- ADGnd inductors kept as 0 ohm resistor due to large power oscillations.
- LDO removed since it is not rad hard

Changes to VMM3 + FEAST

- Analog / AD / Digital power and ground planes simplified and further aligned
- Added Feast Temperature sensors
- Added Rad Hard LDO back into design (but DNP!)
- Even more caps added to all power rails
- DCDC’s and output coil’s remain located away from VMM’s
- Isolated grounds and shields implemented for DCDC and output coils
- DCDC configuration modified slightly to compensate for power droop
- ADGnd inductors kept as 0 ohm resistor due to large power oscillations
- DCDC input output filters reconfigured as anti-parallel
- Anti-parallel caps added to iso dcdc inputs, outputs
- Isolated clip pads installed for iso shields… connected to PGND
- Cutout for input capacitance reduced in size, AGND added across cavern

FEAST + VMM3

- Bench and MM Test Chamber (AZ)

4-May-17	vmm3 + feast			vmm3+feast			same as col a				
mo	mo	mo	mo				mo				
mV	mV	mV	mV	pf	mV /fC	ns	mV	mV	mV		
output rms	output rms	output rms	output rms	c det	gain	peak time	output rms	vmm intrinsi	vmm ripple	ratio ripple/intrinsic	
measured	measured	measured	measured				measured	calculated	extracted		
rms value	rms mean	pp value	pp mean								
0.59	0.61	4.08	3.75	23	3	200	0.59	0.23	0.54	2.36	bench
0.71	0.72	5.40	5.31	23	9	200	0.71	0.69	0.14	0.20	bench
1.08	1.06	7.28	7.69	23	16	200	1.08	1.23	#NUM!	#NUM!	bench
1.00	0.97	7.44	7.20	50	3	200	1.00	0.36	0.93	2.59	mm test
2.54	2.52	19.20	18.40	50	9	200	2.54	1.08	2.30	2.13	mm test
4.34	4.15	29.80	29.70	50	16	200	4.34	1.92	3.89	2.03	mm test
1.06	1.05	7.84	7.19	50	3	200	1.06	0.36	1.00	2.77	mm + shields
2.71	2.61	15.20	16.70	50	9	200	2.71	1.08	2.49	2.30	mm + shields
4.56	4.48	26.00	27.10	50	16	200	4.56	1.92	4.14	2.15	mm + shields

FEAST + VMM3

- Bench with external capacitors

mo	mo	mo	mo				mo			
mV	mV	mV	mV	pf	mV /fC	ns	mV	mV	mV	
output rms	output rms	output rms	output rms	c det	gain	peak time	output rms	vmm intrinsic	vmm ripple	ratio ripple/intrinsic
measured	measured	measured	measured				measured	calculated	extracted	
rms value	rms mean	pp value	pp mean							
0.41	0.49	2.96	2.86	23	3	200	0.41	0.23	0.34	1.49 v
0.61	0.62	4.12	4.49	50	3	200	0.61	0.36	0.49	1.37 v
3.39	3.16	19.80	19.60	243	3	200	3.39	1.29	3.14	2.44 v
0.69	0.72	5.56	5.43	23	9	200	0.69	0.69	#NUM!	#NUM! v
1.41	1.43	9.60	9.95	50	9	200	1.41	1.08	0.91	0.84 v
8.94	8.48	56.40	50.90	243	9	200	8.94	3.86	8.06	2.09 v
1.09	1.06	7.20	7.50	23	16	200	1.09	1.23	#NUM!	#NUM! v
2.11	2.35	17.40	16.30	50	16	200	2.11	1.92	0.88	0.46 v
15.60	14.40	95.20	86.30	243	16	200	15.60	6.86	14.01	2.04 v