Tests of Milano Regulator Board with Long Cables

K. Einsweiler, LBNL

Regulator board tests:

- Comparisons of performance of board with electronic load and different cables.
- Comparisons of module performance with full electrical prototype cables.
- Evaluation of “current compensation” scheme and different passive components.

Regulator Card Tests with Electronic Load

Use several cable configurations:

- Use modified TPCC cable with sense lines connected to supply lines at regulator board for initial testing. Define as “Ideal” cable.
- Use SCT cable supplied by Milano (12m) as a model for Type 1/2 cable, but terminate in an 8-pin Molex connector to provide good connections for remote sensing. Define as “SCT” cable. It has 750mV round-trip drop at 1A current.
- Use realistic Type 3 cables (140m, AWG16 twisted pair, 6 pair analog cable, 6 pair digital cable) between power supply and regulator card. Define as “Real” cable.This cable has a 3.8V round-trip drop at 1A current.

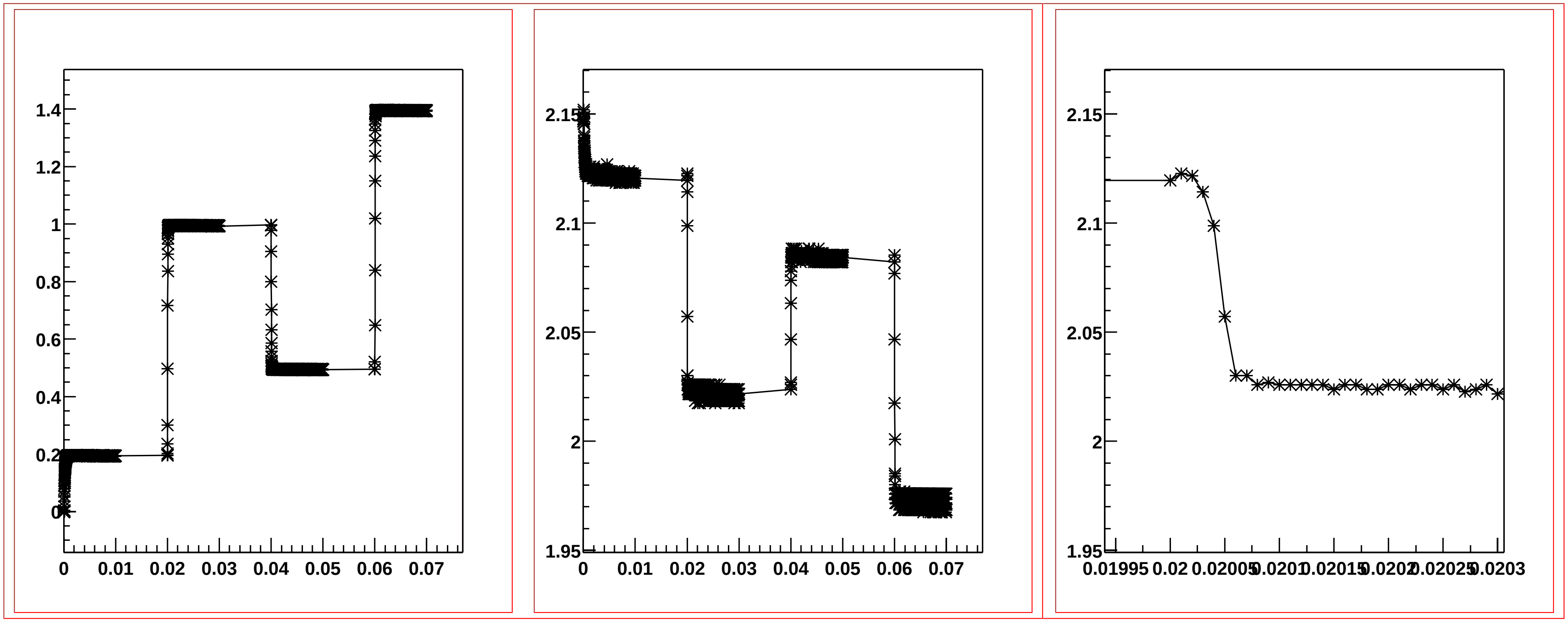
Use Agilent N3300 load system to study transient behavior:

- Programmable load capable of high transient rates (250kA/s for low voltages). So far, used in “CC” mode only, will also try “CR” mode. Includes 16-bit ADC system with 4K buffer to sample voltage and current during transient conditions.

Study different sensing schemes:

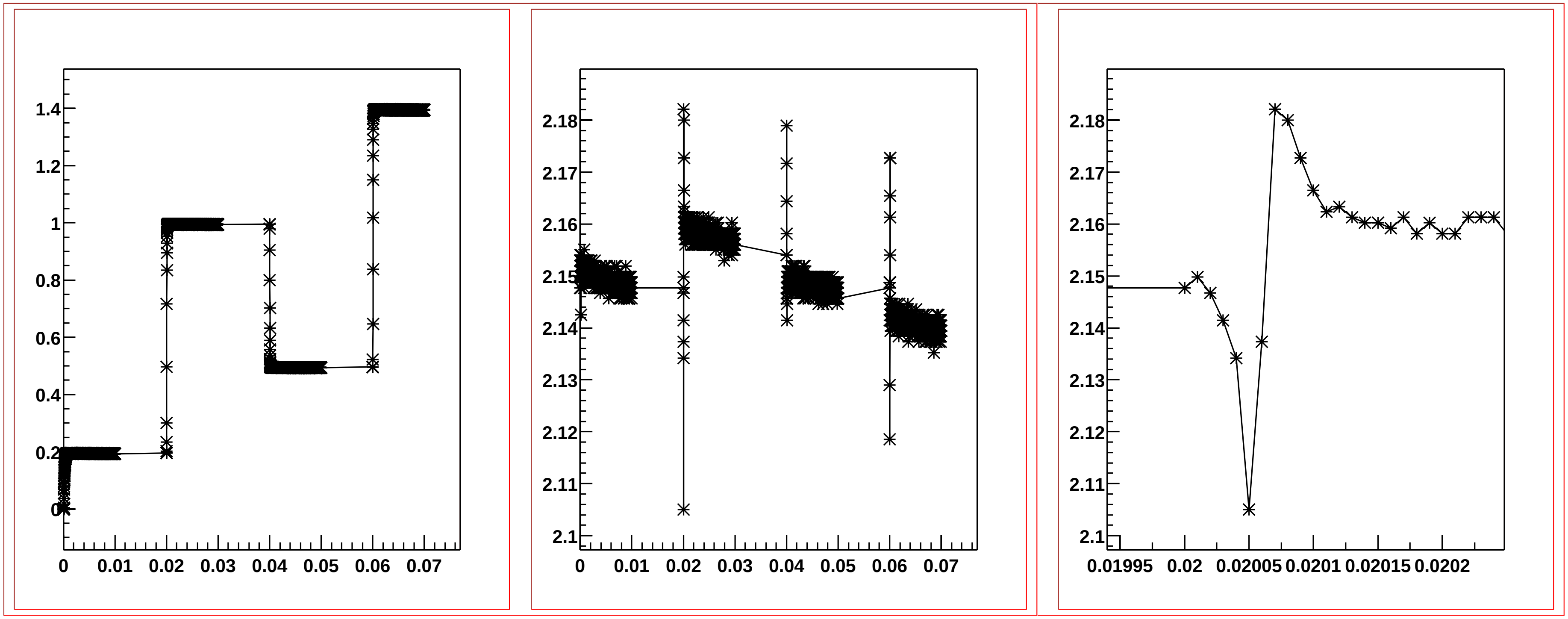
- Milano has implemented standard sensing scheme from vendor (single ground). This scheme has reduced load regulation due to voltage drop in return sense line.
- Milano has implemented the “current compensation” scheme of Jarron, in which a properly chosen resistor compensates for the regulator quiescent current.

Example measurement with load system ("Ideal cable"):



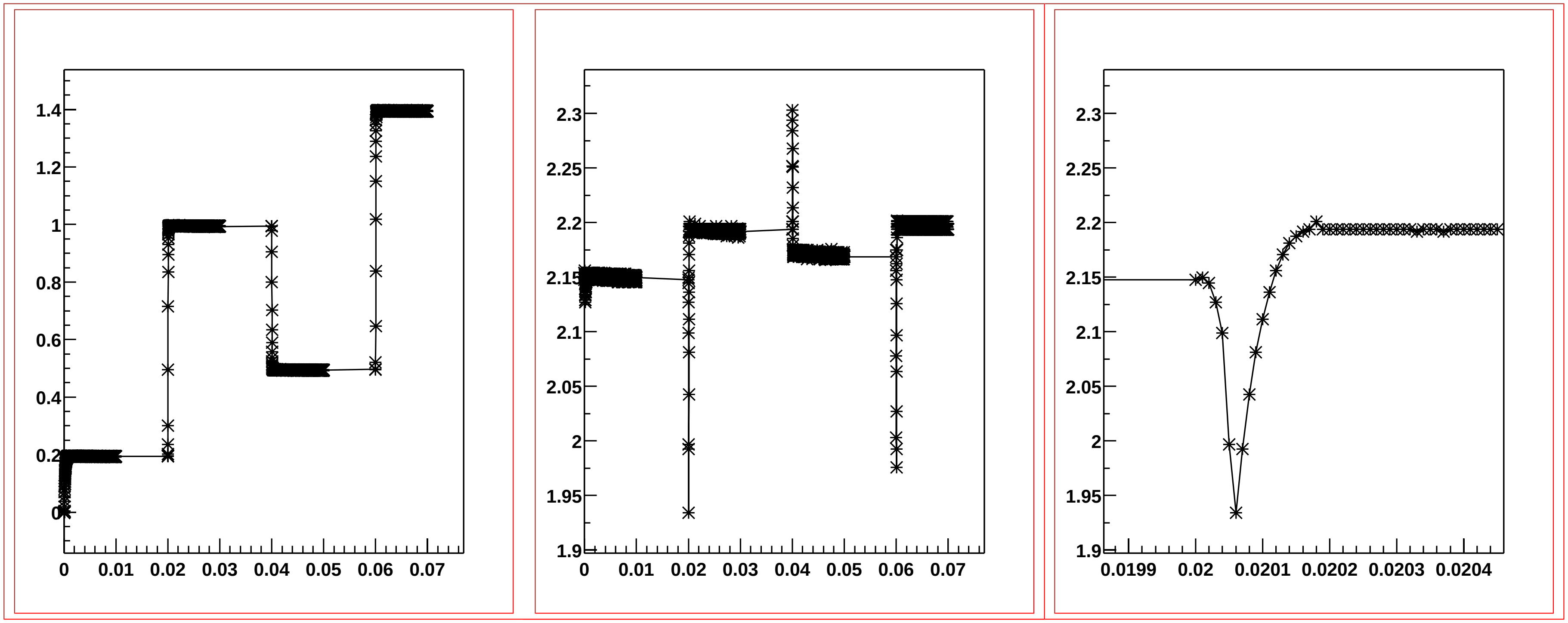
- Use "Ideal" cable for VDD supply.
- Use a program with very high transient slew rate of 100A/ms. Plot on left shows four different current values used, with 20ms between each transient.
- Set up ADC to sample for 1000 points with 10μs period at each transient change.
- Plot in the middle shows voltage sampled at load. In the "Ideal" cable there is no remote sensing, so the voltage drop of the short power cable is apparent.
- Plot on the right is a zoom of the transient voltage change when the current is changed from 0.2A to 1.0A

Measurement of “SCT cable” with load system:



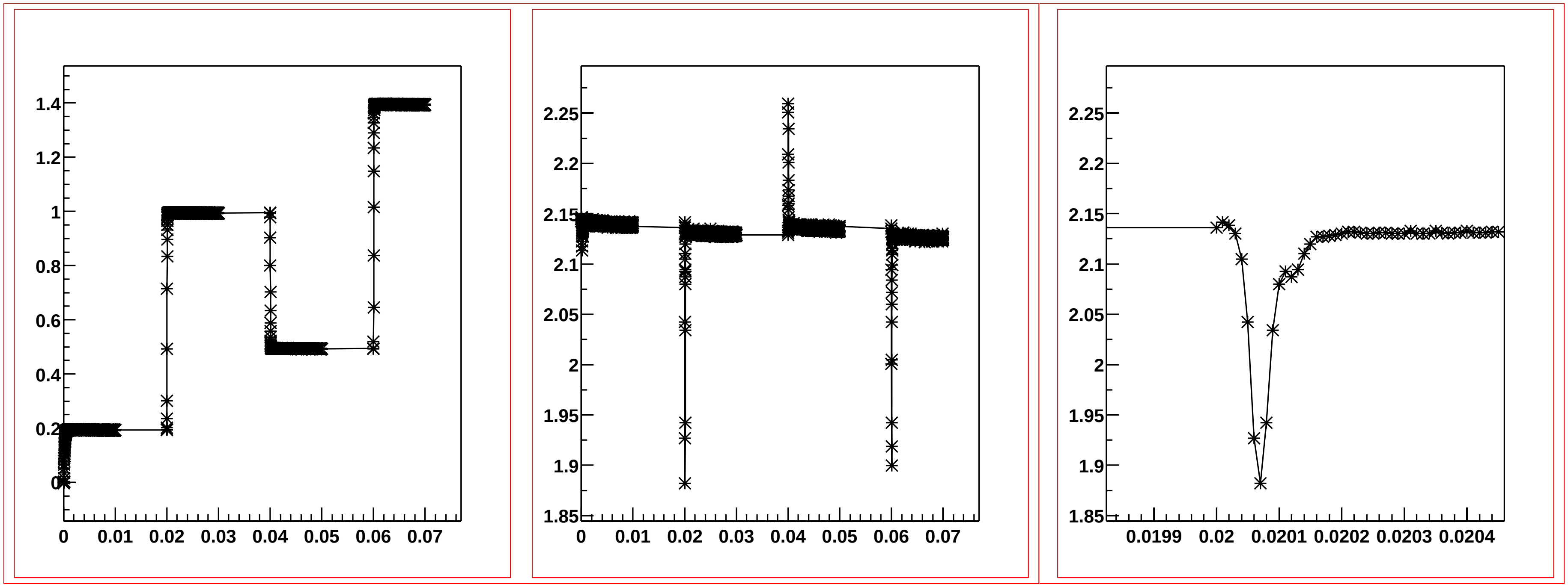
- Use 12m SCT cable in remote sense mode. Still have only 2m cable to supply.
- Use a program with very high transient slew rate of 100A/ms. Plot on left shows four different current values used, with 20ms between each transient.
- Plot in the middle shows voltage sampled at load. In this case, the remote sensing corrects for almost all of the voltage drop.
- Plot on the right is a zoom of the transient voltage change when the current is changed from 0.2A to 1.0A. Transient observed is (-40mV, +30mV).

Measurement of "Real cable" with load system:



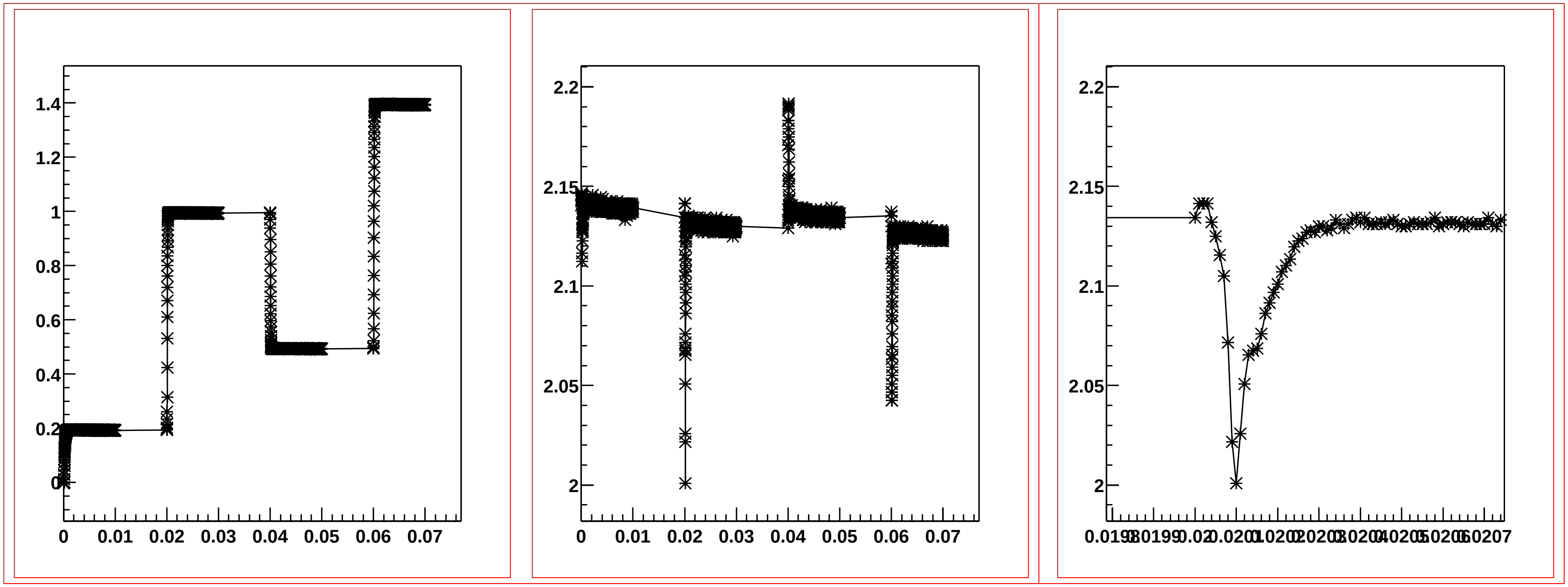
- Use 12m SCT cable in remote sense mode. Use 140m realistic cable to 10V supply
- Use a program with very high transient slew rate of 100A/ms. Plot on left shows four different current values used, with 20ms between each transient.
- Plot in the middle shows voltage sampled at load. In this case, the load regulation is coupled with line regulation, and see a 50mV step instead of 10mV step.
- Plot on the right is a zoom of the transient voltage change when the current is changed from 0.2A to 1.0A. Transient observed is now 200mV, due to large voltage drop on long cable to regulator input (large ΔI causes large ΔV on regulator input).

Measurement of “Real cable” and “current compensation”:



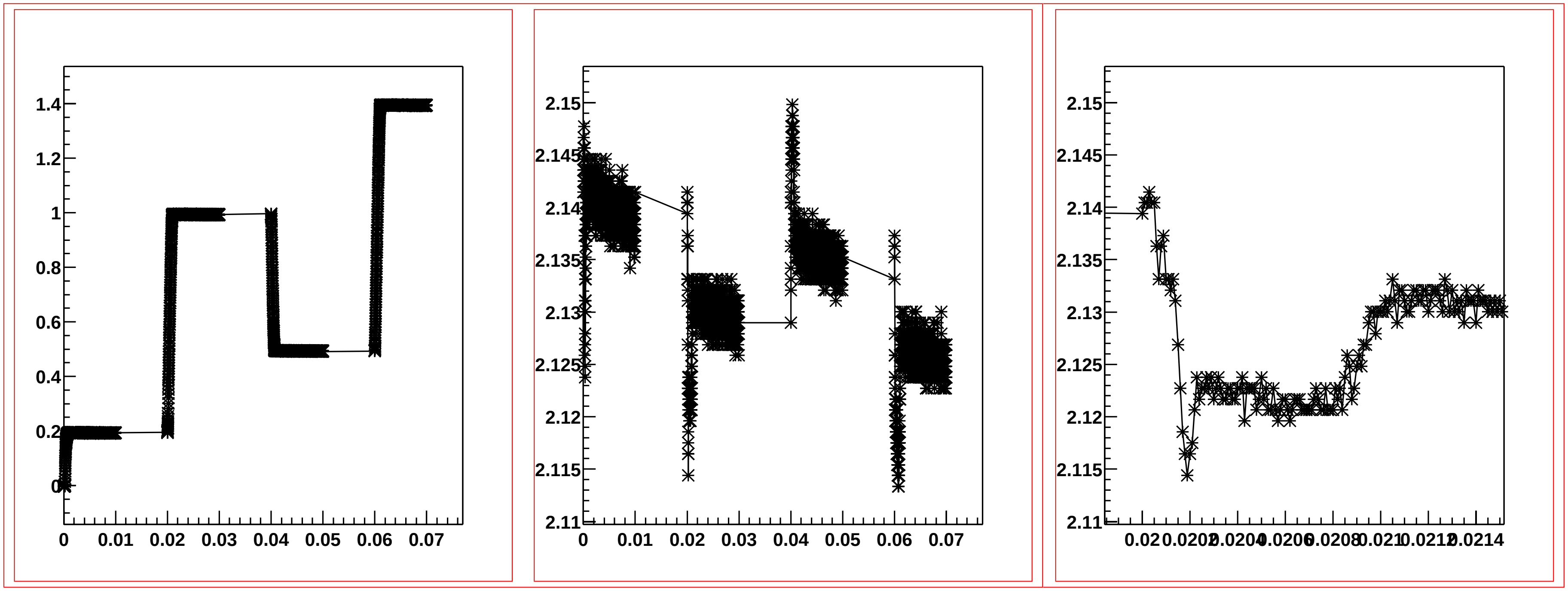
- Use 12m SCT cable in remote sense mode. Use 140m realistic cable to 10V supply
- Use a program with very high transient slew rate of 100A/ms. Plot on left shows four different current values used, with 20ms between each transient.
- Plot in the middle shows voltage sampled at load. In this case, the regulation is very much improved compared to the previous case, with less than 10mV steps.
- Plot on the right is a zoom of the transient voltage change when the current is changed from 0.2A to 1.0A. Transient observed is about 250mV, and the time structure is the same as for the conventional remote sense mode of operation.

Measurement of “Real cable” and “current compensation”:



- Use 12m SCT cable in remote sense mode. Use 140m realistic cable to 10V supply
- Use a program with moderate transient slew rate of 10A/ms. Plot on left shows four different current values used, with 20ms between each transient.
- Plot in the middle shows voltage sampled at load. The regulation is the same as for the previous case, with less than 10mV steps.
- Plot on the right is a zoom of the transient voltage change when the current is changed from 0.2A to 1.0A. Transient observed is reduced to about 150mV, and has a longer time structure than before.

Measurement of “Real cable” and “current compensation”:



- Use 12m SCT cable in remote sense mode. Use 140m realistic cable to 10V supply
- Use a program with low transient slew rate of 1A/ms. Plot on left shows four different current values used, with 20ms between each transient.
- Plot in the middle shows voltage sampled at load. The regulation is the same as for the previous case, with less than 10mV steps.
- Plot on the right is a zoom of the transient voltage change when the current is changed from 0.2A to 1.0A. Transient observed is significantly reduced to about 25mV, and has a still longer time structure than before.

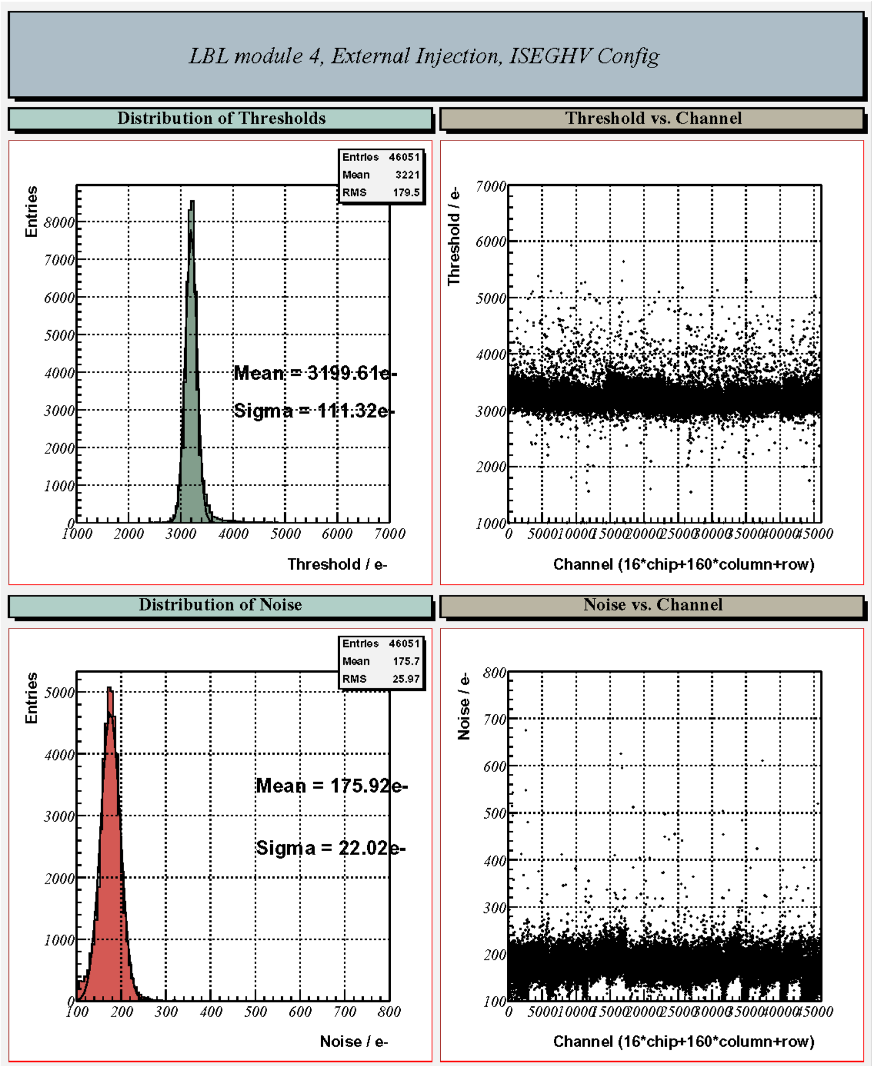
Study values of passive components:

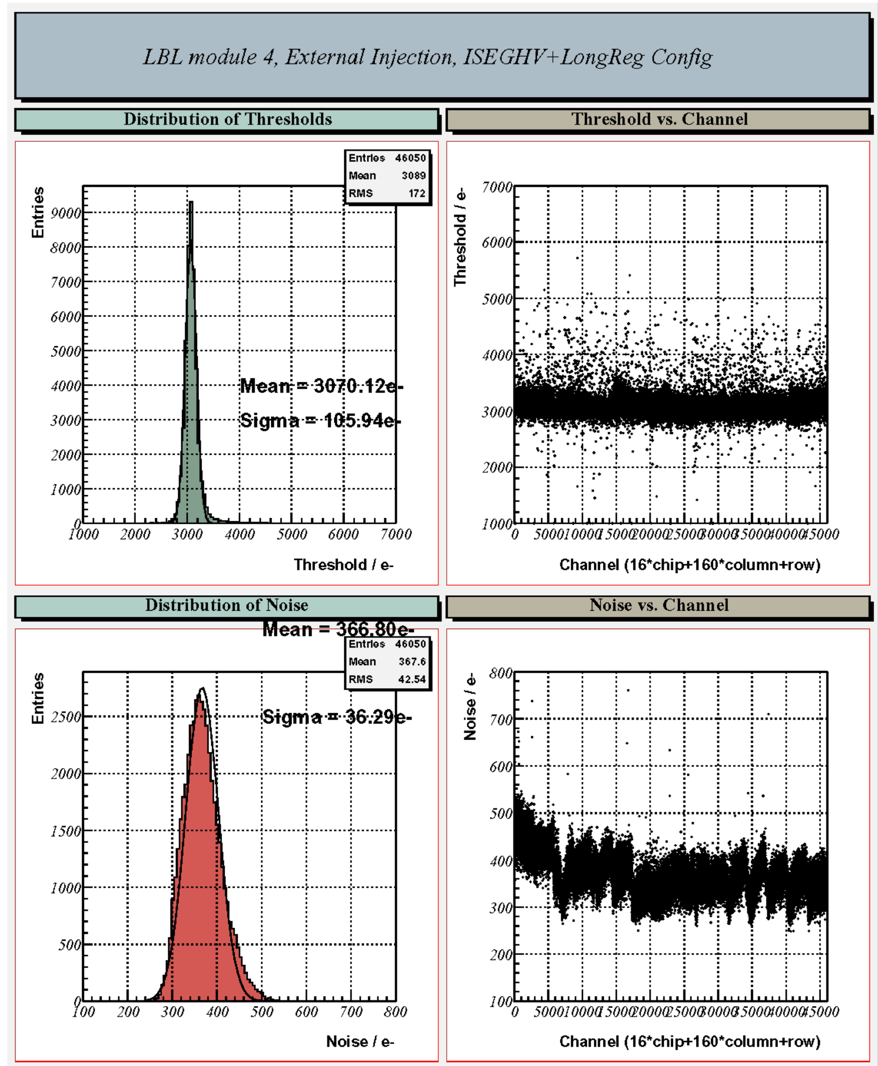
- Varied input filter capacitor from standard 10μF Tantalum to 22μF ceramic (large change in ESR). This had essentially no effect on operation with the realistic cable and the electronic load.
- Removed small 1nF filter capacitor (C97) placed across the sense lines near the regulator. This had no effect on the behavior of the regulator with the electronic load, but it had a large effect on the behavior when operated with a real pixel module. The previously observed unstable behavior with 50KHz and 100KHz resonances in the regulator output ripple essentially disappeared when this filter capacitor was removed... The sense nodes are very sensitive !

Study performance of LBL_4 with different configurations:

- First, define usual setup as a reference. This means Keithley 2410 with 1m coax cable for HV, and Agilent supplies with 1m cable for LV.
- Then compare this to operation of the module with ISEG HV unit connected with a 150m long cable (6 twisted pairs of AWG24, with overall shielding). This cable simulates the complete Type 1/2/3/4 chain from PP0 to the HV supply.
- Next, connect the LV to the regulator board using the “Ideal cable” arrangement.
- Finally, connect the LV with the “Real cable” arrangement.
- Note present disk micro-cables do not support remote sense, so sensing stops at PP0 Elco connector. There is an additional roughly 150mV round-trip drop.

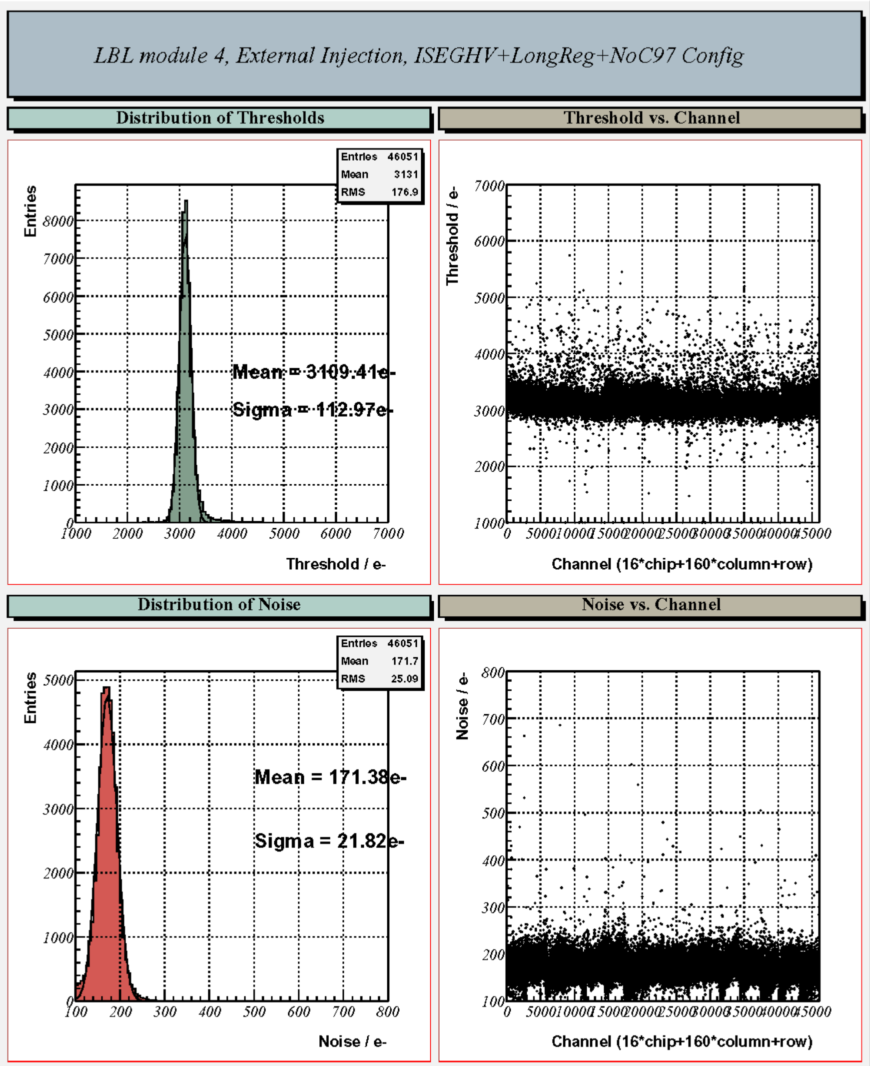
- Compare performance with ISEG HV to ISEG HV plus regulator with long cables:

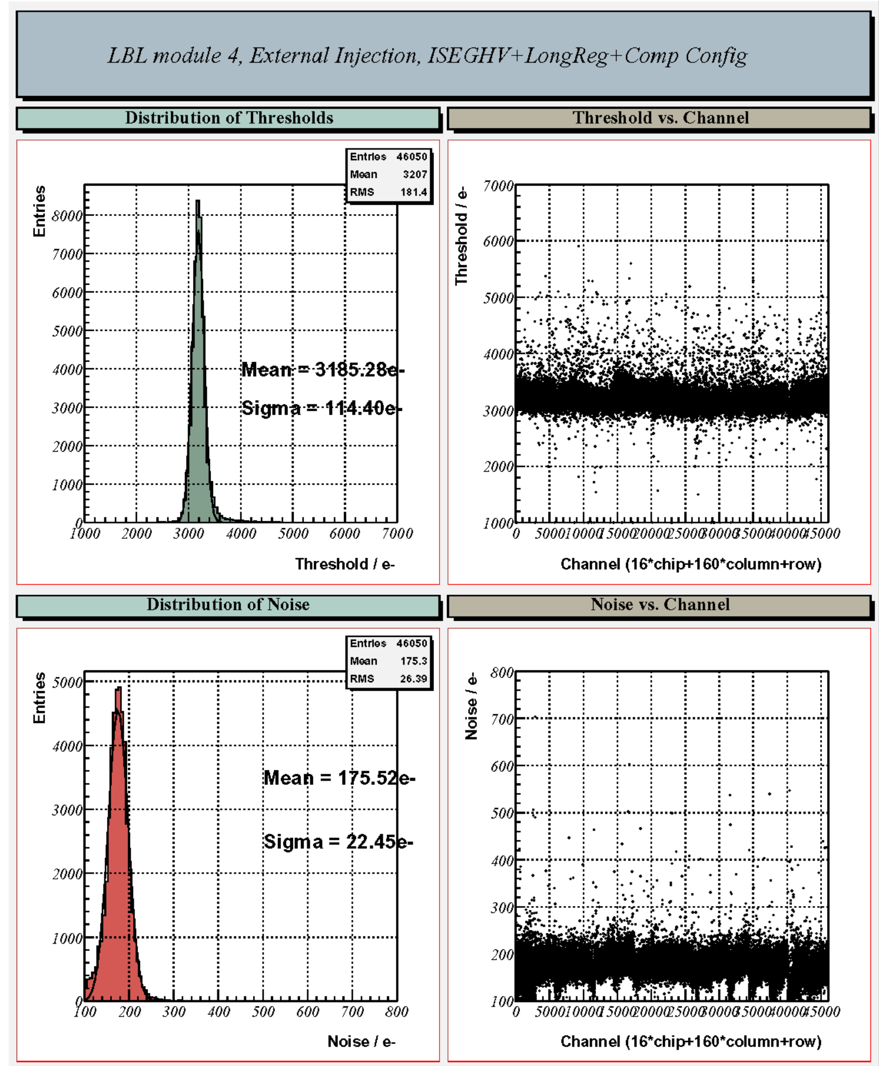




- ISEG HV alone is identical to reference scan.
- Regulator with long cables shows very significant ripple, which increases the measured noise as well. This was cured by removing (optional) filter cap on sense.

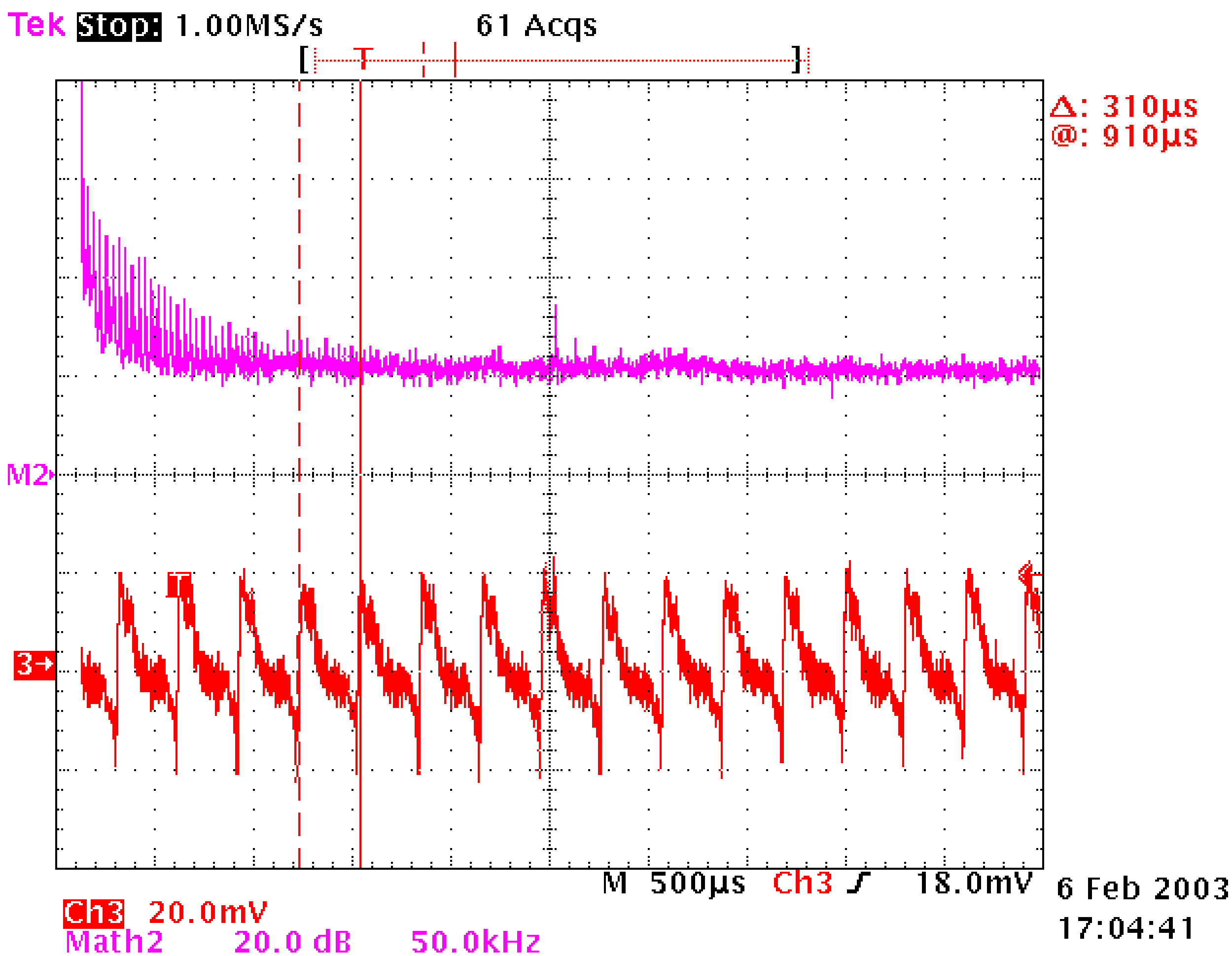
- Compare performance of standard regulation and current compensation mode:





- Standard regulation has optional sense filter cap removed.
- Both scans show performance identical to that of the reference scan.

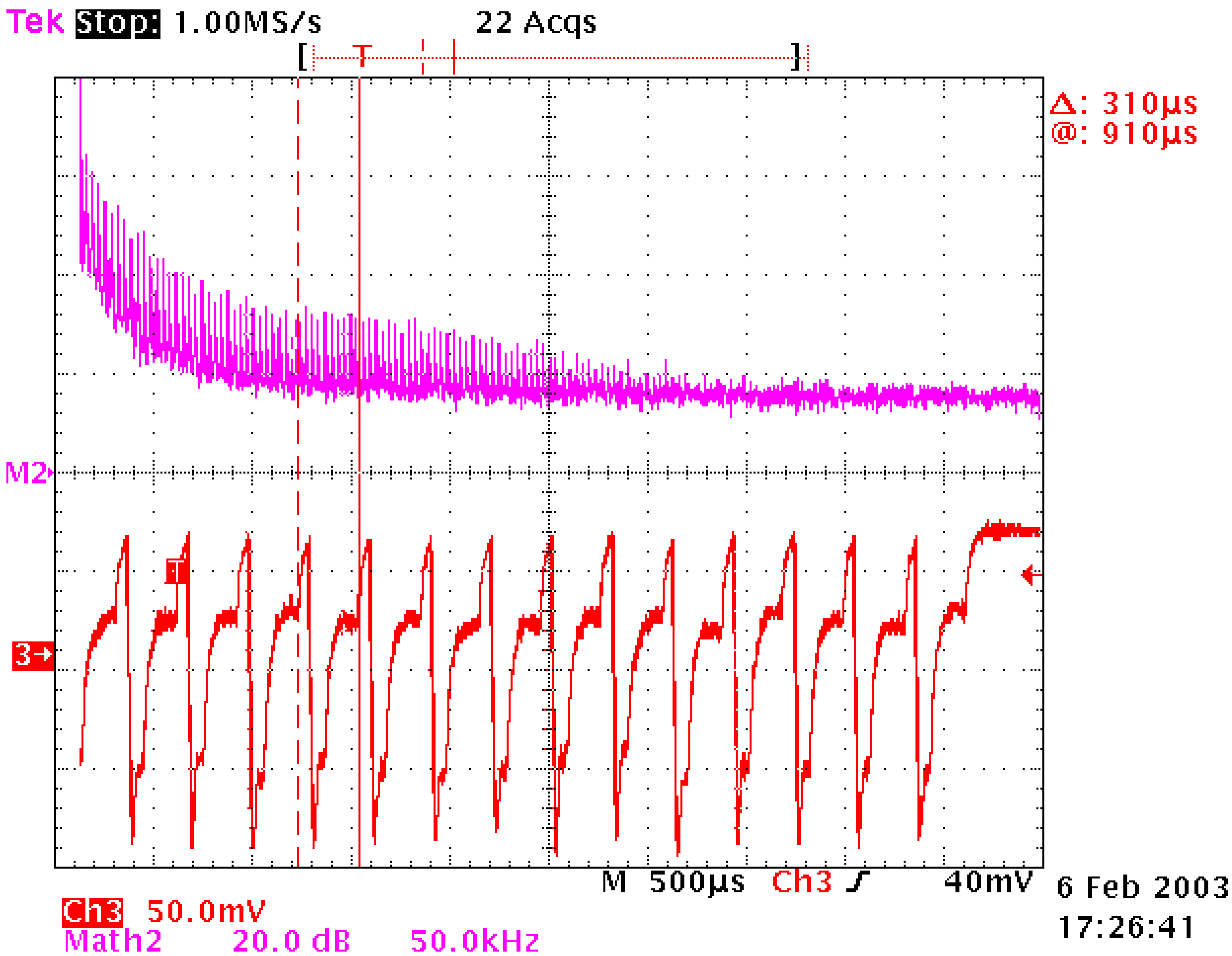
• Look at time-dependence voltage at regulator output (before 12m cable):



• Observed time structure is the inject/trigger interval of 300µs used in the threshold scan.

• Observed amplitude is +/-20mV peak to peak. This reflects the operation of the remote sense circuitry to keep a constant voltage at the pixel module.

- Look at time-dependence voltage at regulator input (after 140m cable):



- Observed time structure is the inject/trigger interval of 300µs used in the scan.
- Observed amplitude is 150mV peak to peak. This reflects the variation of the voltage drop with current, and corresponds to about 40mA peak to peak variation in the current.

Conclusions and Next Steps

- First operation of a module with the full electrical model of services for LV and HV. First measurements suggest that the performance is essentially unchanged (at least for a threshold scan).
- More sophisticated measurements will follow. This includes more complete studies with the programmable load, including CR mode. Tests will also be done using the long barrel Type 0 cable which Walter has sent to LBL. Will also include more noise-sensitive scans, such as source scans and readout all mode scans, and operation of multiple modules.
- Continue to find sensitivity to details of sense lines. We should be sure to treat these as “low noise” analog lines in PP1/PP0 and service panel layout.
- Characterization of performance with programmable load shows good performance for the standard scheme. Even better performance is seen for the “current compensation” scheme of Jarron. Should we adopt this scheme as a “baseline” ?
- If so, the next generation of regulator prototype should implement all 16 channels using this scheme. Note that we also require a different voltage range for VDD, VDDA, and VVDC, so future boards should have the identity of these channels fixed, and the appropriate resistor values loaded.

- In principle, the “current compensation” scheme allows us to operate the remote sense with two small wires. Propose that for the Type 1 and Type 2 cables, we should retain the original scheme of three large and one small conductor for a sensed power supply. However, we could consider changing the wire size for the Type 0 cables (4 “thick” wires instead of 6 for the complete micro-cable).

Further Comments:

- Operation of modules during the PS irradiation requires use of relatively long services (30m). This is too difficult without the use of a regulator board. Since the board is very radiation tolerant, it can easily be placed near TPCC’s (7m from modules) and operated in remote sense mode.
- Also, propose that we try to operate modules at H8 using realistic cable plant and remote-sense operation of regulator board. The H8 environment has proven to be a useful “noisy” environment that often shows problems not seen in the lab.
- We should make a preliminary plan for how many regulator boards, and with what features, we need to fabricate in order to carry out our work over the next 6-9 months. This will also naturally feed into the cable and power supply PRR’s in June and September this year.