TESS FPE Development Log

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6/9/2015 Stress Simulations of Parallel Drivers

We have promised that the drivers will be immune to bad sequencer programming. The hazard is that at unusually high clock frequencies and duty cycles the dissipation will be too high.

Since the driver voltage regulators implement current and dissipation limits, they are not the first concern. Each regulator powers the six drivers for a single CCD, so the worst case is rapid clocking of a single driver, focusing all of the available power on a few components. The voltage swing also matters: I am assuming we will soon restict that to 10V.

The files for these sims are from commit 89d13541bd. The simulated ParallelReg and ParallelPair schematics are in AE/Simulation/Annex. They have added current monitors and do not exactly correspond to any revision of the mainline schematics. They suggest important revisions: see below. To reproduce this result

```
cd tess/AE/Simulation
cp Annex/ParallelPair.sch Annex/ParallelReg.sch .
make parallelstress.txt
```

It'll make lots of SPICE spewage an your screen. Here's the result in parallelstress.txt:

```
pixel_period = 1.333333e-07
total_power = 8.358019e-01
ccd_dissipation = -2.41912e-05
booster_q1_dissipation = 1.764529e-07
booster_q2_dissipation = 1.006460e-04
booster_r7_dissipation = 2.628663e-01
regulator_q1_dissipation = 9.834006e-02
regulator_q2_dissipation = 1.371268e-01
regulator_r21_dissipation = 1.144064e-03
regulator_r22_dissipation = 1.225501e-03

pixel_period = 2.000000e-07
total_power = 7.661961e-01
ccd_dissipation = -2.42715e-05
booster_q1_dissipation = 2.537668e-07
booster_q2_dissipation = 9.615248e-05
booster_r7_dissipation = 2.609991e-01
regulator_q1_dissipation = 9.764662e-02
regulator_q2_dissipation = 1.362251e-01
regulator_r21_dissipation = 1.128223e-03
```

```
regulator_r22_dissipation = 1.209362e-03

pixel_period = 2.666667e-07
total_power = 7.251575e-01
ccd_dissipation = -2.41384e-05
booster_q1_dissipation = 2.794415e-07
booster_q2_dissipation = 9.383525e-05
booster_r7_dissipation = 2.567996e-01
regulator_q1_dissipation = 9.668702e-02
regulator_q2_dissipation = 1.349711e-01
regulator_r21_dissipation = 1.106448e-03
regulator_r22_dissipation = 1.187129e-03

pixel_period = 4.000000e-07
total_power = 6.702551e-01
ccd_dissipation = -2.68291e-05
booster_q1_dissipation = -1.13272e-08
booster_q2_dissipation = 1.185802e-04
booster_r7_dissipation = 2.412091e-01
regulator_q1_dissipation = 9.362991e-02
regulator_q2_dissipation = 1.310063e-01
regulator_r21_dissipation = 1.039114e-03
regulator_r22_dissipation = 1.118229e-03

pixel_period = 5.333333e-07
total_power = 6.314401e-01
ccd_dissipation = 1.036446e-03
booster_q1_dissipation = 3.745419e-05
booster_q2_dissipation = 7.616798e-03
booster_r7_dissipation = 2.221996e-01
regulator_q1_dissipation = 8.973050e-02
regulator_q2_dissipation = 1.268042e-01
regulator_r21_dissipation = 9.567884e-04
regulator_r22_dissipation = 1.048598e-03

pixel_period = 8.000000e-07
total_power = 5.969821e-01
ccd_dissipation = 2.981062e-03
booster_q1_dissipation = 1.071532e-04
booster_q2_dissipation = -5.83759e-04
booster_r7_dissipation = 2.116022e-01
regulator_q1_dissipation = 8.761025e-02
regulator_q2_dissipation = 1.233901e-01
regulator_r21_dissipation = 9.134624e-04
regulator_r22_dissipation = 9.914689e-04
```

```
pixel_period = 1.066667e-06
total_power = 5.654631e-01
ccd_dissipation = 7.911254e-04
booster_q1_dissipation = 9.835954e-05
booster_q2_dissipation = -7.47503e-04
booster_r7_dissipation = 1.961213e-01
regulator_q1_dissipation = 8.398984e-02
regulator_q2_dissipation = 1.184516e-01
regulator_r21_dissipation = 8.412774e-04
regulator_r22_dissipation = 9.137481e-04

pixel_period = 1.600000e-06
total_power = 5.646182e-01
ccd_dissipation = 3.090247e-04
booster_q1_dissipation = 3.835051e-02
booster_q2_dissipation = -9.39081e-04
booster_r7_dissipation = 1.548198e-01
regulator_q1_dissipation = 8.591047e-02
regulator_q2_dissipation = 1.206368e-01
regulator_r21_dissipation = 8.725175e-04
regulator_r22_dissipation = 9.491317e-04

pixel_period = 2.133333e-06
total_power = 1.937990e+00
ccd_dissipation = 2.245338e-01
booster_q1_dissipation = 4.722572e-01
booster_q2_dissipation = 1.761843e-01
booster_r7_dissipation = 1.229537e-01
regulator_q1_dissipation = 3.152604e-01
regulator_q2_dissipation = 4.312550e-01
regulator_r21_dissipation = 1.242146e-02
regulator_r22_dissipation = 1.256129e-02

pixel_period = 3.200000e-06
total_power = 2.071263e+00
ccd_dissipation = 2.946155e-01
booster_q1_dissipation = 3.600199e-01
booster_q2_dissipation = 3.323593e-01
booster_r7_dissipation = 9.073041e-02
regulator_q1_dissipation = 3.378139e-01
regulator_q2_dissipation = 4.610033e-01
regulator_r21_dissipation = 1.432644e-02
regulator_r22_dissipation = 1.487209e-02
```

```
pixel_period = 4.266667e-06
total_power = 1.627515e+00
ccd_dissipation = 2.273986e-01
booster_q1_dissipation = 2.697074e-01
booster_q2_dissipation = 2.574485e-01
booster_r7_dissipation = 6.866426e-02
regulator_q1_dissipation = 2.669412e-01
regulator_q2_dissipation = 3.629527e-01
regulator_r21_dissipation = 8.775428e-03
regulator_r22_dissipation = 9.541275e-03

pixel_period = 6.400000e-06
total_power = 1.141460e+00
ccd_dissipation = 1.515176e-01
booster_q1_dissipation = 1.797313e-01
booster_q2_dissipation = 1.721775e-01
booster_r7_dissipation = 4.547011e-02
regulator_q1_dissipation = 1.879895e-01
regulator_q2_dissipation = 2.548577e-01
regulator_r21_dissipation = 4.251466e-03
regulator_r22_dissipation = 5.192248e-03

pixel_period = 8.533333e-06
total_power = 8.937256e-01
ccd_dissipation = 1.130203e-01
booster_q1_dissipation = 1.359123e-01
booster_q2_dissipation = 1.292140e-01
booster_r7_dissipation = 3.403328e-02
regulator_q1_dissipation = 1.468536e-01
regulator_q2_dissipation = 1.990946e-01
regulator_r21_dissipation = 2.563844e-03
regulator_r22_dissipation = 3.597144e-03
```

The circuit in these sims omits the 1Ω 1W resistors in the Booster outputs from FPE-6.1-RR9 and earlier versions. The Booster robustly prevents overlap conduction between Q1 and Q2 (and the regulator is current-limited anyway), so these are not needed. They actually dissipated very little. The output waveforms are cleaner without them. R7 in the boosters is 365Ω, up from 200Ω in FPE-6.1-RR9, slowing the rise times and reducing its dissipation. The CCD model is a lumped-constant approximation to the distributed parallel clock resistance/capacitance, with parameters adjusted to match Jerry's measurements of 5.1 driver waveforms.

R7 remains the most problematic component, dissipating over 1/4W at the maximum clock frequency. It is a 1/10W component that really needs to be 1/2W.

For the Booster transistors, maximum dissipation is about 1/2W for Q1. Q2 is a bit less. According to the IR data sheets, these have thermal resistance junction to the PC board of 26C/W, so that's not a large temperature rise.

The regulator transistors Q1 and Q2 are thermally protected, and probably close to their limits at periods $\approx 3\mu$s, so the actual power dissipation at periods in that range may be lower.

8/7/2015 Stress Simulations of Charge Pump

The worrisome components turn out to be some resistors. At 26C/W thermal resistance, the MOSFETS can handle ¿1W dissipation apiece. The bipolars dissipate ¡100mW apiece, even driving short circuits. After much exploration, I got the following model:

```
With:
R1, R4 = 12.1
R10 = 4.99
R12 = 182
R13 = 16.2

0mA 29.4V
10mA 26.5V
20mA 24.3V
30mA 21.9V
40mA 9.7V

Positive output shorted:
mean(vm#branch)*12-mean(vp#branch)*15v-mean(vl#branch)*5v = 1.670607e+00

R10
mean((xpp.ve-xpp.vac)^2)/4.99 = 1.440800e-01

R11
mean((5v-xpp.pr)^2)/100 = 2.976090e-01

R13
mean((xpp.pt-op)^2)/16.2 = 6.965483e-02

Q5, Q6
mean((xpp.vpp-xpp.ve)*v.xpp.vq5#branch) = 5.688234e-02
mean((xpp.ve-xpp.vpm)*v.xpp.vq6#branch) = 6.403048e-02
```

```
Negative output shorted:

R12
mean((xpp.nt-om)^2)/182 = 1.386983e-01

High but not excessive load case:

positive out:
mean(op)/2k+16ma = 2.730725e-02
mean(op) = 2.261451e+01
(mean(op)/2k+16ma)*(mean(op)) = 6.175400e-01

negative out:
mean(om)/50k = -1.11578e-03
mean(om) = -5.57888e+01
mean(om^2)/50k = 6.224791e-02

Total power in:
mean(vm#branch)*12-mean(vp#branch)*15v-mean(vl#branch)*5v = 1.073801e+00
63% efficiency
```

Thus, we need a bit of ratings increase on a few resistors (issue #91).

```
R10 should be 1/4W
R11 should be 1/2W
R12 should be 1/4W
R13 should be 1/8W
```