ITkPixV1.1 module QC tool - Injection Capacitance

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ITkPix Module Electrical QC meeting

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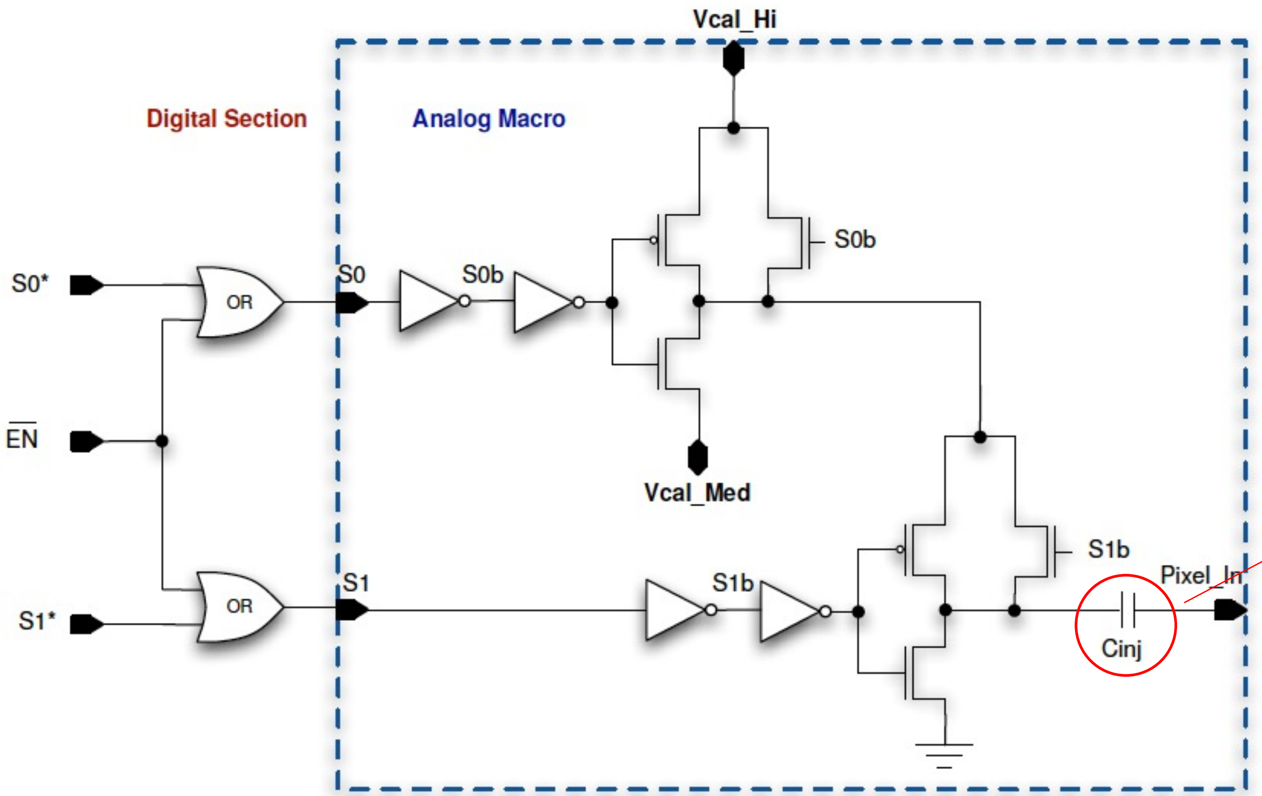
BERKELEY LAB

Injection capacitance

- Each pixel is equipped with a calibration injection circuit – we can inject a known charge and record response of pixel.
- Injected charge depends on ΔV and C_{inj}



We want to measure this and determine if it is close enough to nominal value (**8.02 f**F)

RD53b manual: Section 6

Capmeasure circuit

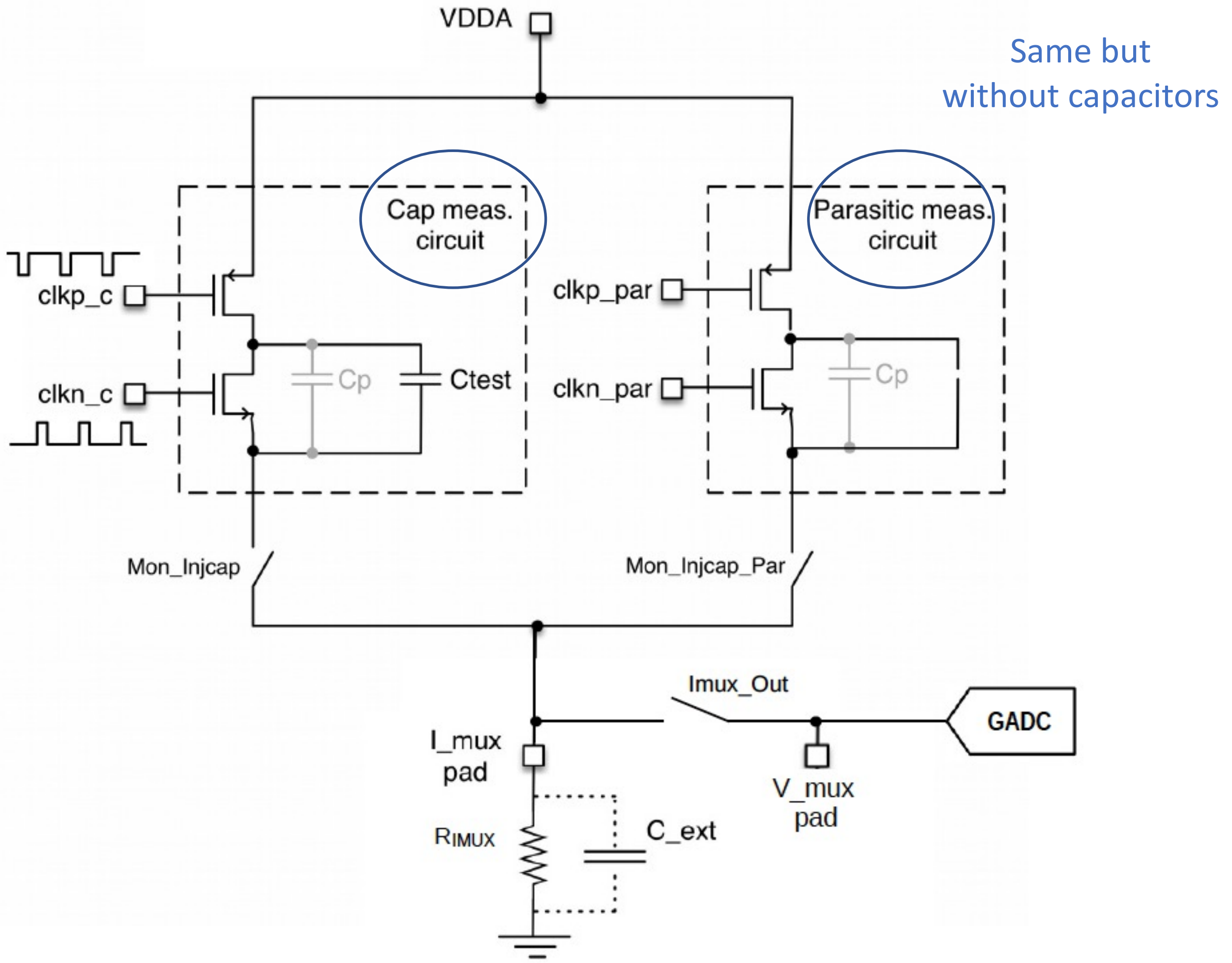
- Each chip is equipped with a dedicated circuit to measure injection capacitance: *capmeasure circuit* (see Section 13.8)

$$C_{meas} = 100(C_{pix} + \Delta C) + C_{par}$$

→ Solve for C_{pix}, measure C_{meas} and Cpar

- C_{meas} measured with IMUX(10)
- C_{par} measured with IMUX(11)

ΔC: Added capacitance due to different connections in pixel and capmeasure circuit. ΔC = 0.48 fF (from layout extraction)



Scripts

- Injection capacitance measurement scripts are modelled after SLDO VI scan tool developed by Jay Chan (here)
- They are currently structured in the following way:

Repo, MR

Module QC measurement tools

- Measure capmeasure circuit 10 times
- Calls module QC data tools
- Record in json file:
  1. VMUX30 – GND
  2. IMUX4 – VDDA from capmeas
  3. IMUX10 - $V_{capmeas}$
  4. IMUX11 - $V_{parasitic}$
  5. IMUX63 - GND
  6. $VDDA_{capmeas}$
  7. $I_{capmeas}$
  8. $I_{parasitic}$

Repo, MR

Module QC data tools

- Convert IMUX values from voltage to current
- Subtract ground and apply multiplicative factors to VMUX

Repo, MR (todo)

Module QC analysis tools

- Calculate C_{pix}
- Make diagnostic plots
- Make QC decision

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```
{
    "Identifiers": {
        "ChipID": 15,
        "Name": "JohnDoe_0",
        "Institution": "",
        "TestType": "CAPMEAS",
        "TimeStart": 1664222583.834281,
        "TimeEnd": 1664222606.884463
    },
    "Measurements": {
        "vmux4": {
            "X": false,
            "Unit": "V",
            "Values": [
                0.593639,
                0.594479,
                0.593897
            ]
        },
        "vmux30": {
            "X": false,
            "Unit": "V",
            "Values": [
                0.0026395,
                0.0026408,
                0.0026416
            ]
        },
        "imux10": {
            "X": false,
            "Unit": "V",
            "Values": [
                0.050899299999999995,
                0.0508836,
                0.0509288
            ]
        },
        "imux11": {
            "X": false,
            "Unit": "V",
            "Values": [
                0.0045428,
                0.004542900000000001,
                0.004544800000000001
            ]
        },
```

```
        "imux63": {
            "X": false,
            "Unit": "V",
            "Values": [
                3.44e-05,
                3.43e-05,
                3.44e-05
            ]
        },
        "VDDA_capmeas": {
            "X": true,
            "Unit": "V",
            "Values": [
                1.181999,
                1.1836764,
                1.1825108
            ]
        },
        "Icapmeas_cir": {
            "X": true,
            "Unit": "A",
            "Values": [
                9.651959999999999e-06,
                9.64856e-06,
                9.657440000000001e-06
            ]
        },
        "Icapmeas_par": {
            "X": true,
            "Unit": "A",
            "Values": [
                3.8065999999999999e-07,
                3.8042000000000017e-07,
                3.8064000000000016e-07
            ]
        }
    },
```

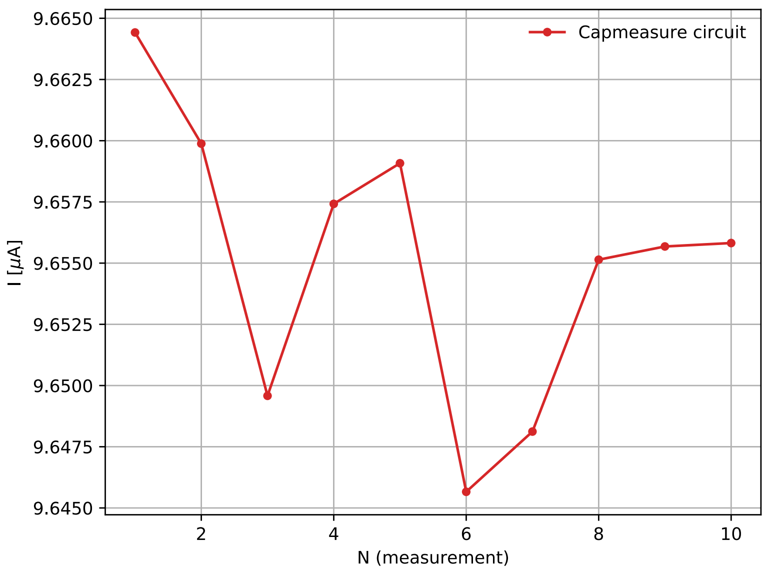
Diagnostic plots

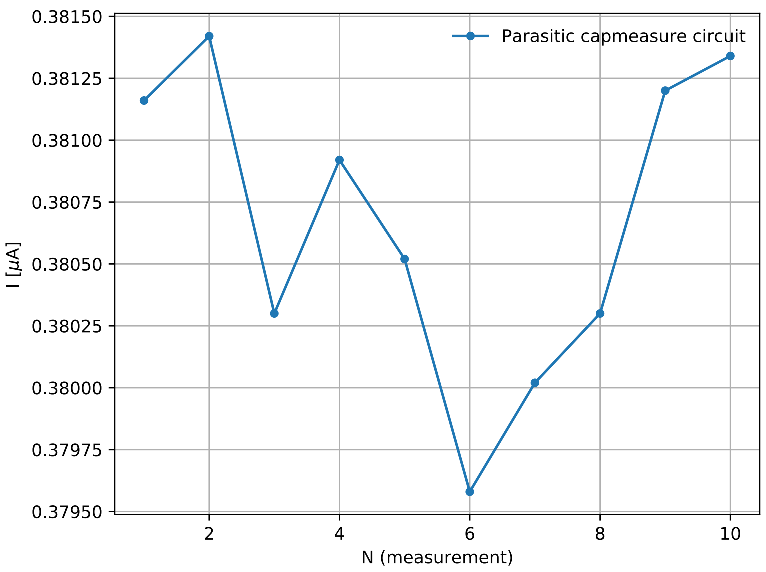
[Repo](), MR (todo)

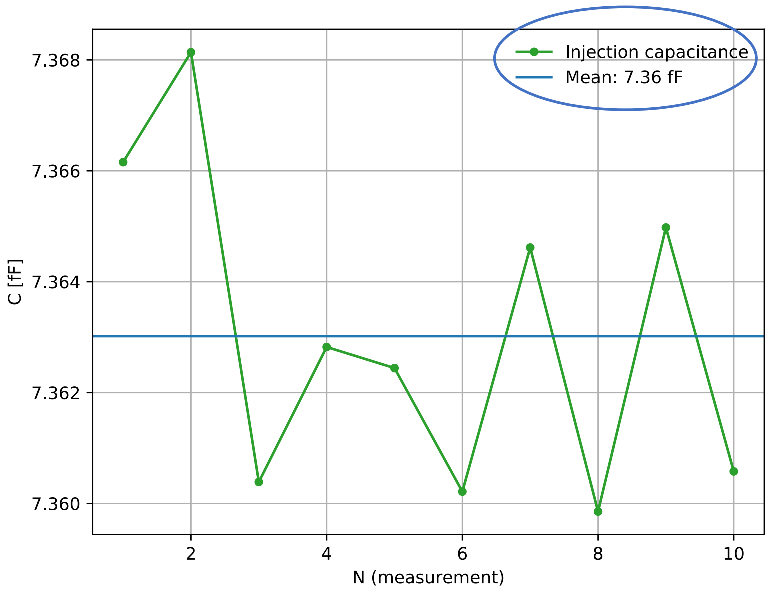
- The following plots are made in **analyze_CAPMEAS.py** in:

Module QC **analysis** tools

Simple plots showing $I_{capmeas}$, $I_{parasitic}$, and C_{pix} for each measurement.







Compare average C_{pix} (7.36 fF) to nominal value (8.03 fF) → this SCC (3D, unbiased) has C_{pix} 8% lower than nominal

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Repo, MR

Module QC data tools

- Convert IMUX values from voltage to current
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Repo, MR (todo)

Module QC analysis tools

- Calculate C_{pix}
- Make diagnostic plots
- Make QC decision

Scripts

- Injection capacitance measurement scripts are modelled after SLDO VI scan tool developed by Jay Chan (here)
- They will be **restructured**:

Repo, MR

Module QC measurement tools

- Measure capmeasure circuit 10 times
- Record in json file:
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Repo, MR

Module QC data tools

- Convert IMUX values from voltage to current
- Subtract ground and apply multiplicative factors to VMUX

Repo, MR (todo)

Module QC analysis tools

- Calls module QC data tools
- Store in json file:
  1. $VDDA_{capmeas}$
  2. $I_{capmeas}$
  3. $I_{parasitic}$
  4. C_{pix}
- Calculate C_{pix}
- Make diagnostic plots
- Make QC decision

Summary & next steps

- Scripts to measure injection capacitance of ITkPixv1.1 chips are in progress
- Some restructuring is needed; feedback at this stage is welcome
- Need to discuss:
  1. When/how scripts will **communicate with localDB and productionDB**
  2. Criteria for module passing/failing injection capacitance measurement test

Backup

From ITkPix1.1 module QC document:

C.3 Injection Capacitance

See [3] Section 13.8.

$$C_{\text{pix}} = (C_{\text{meas}} - C_{\text{par}})/100 - \Delta C$$

With

- $C_{\text{meas}} = \left|\frac{I_{\text{capmeas}}}{10\,\text{MHz}\cdot VDDA_{\text{capmeas}}}\right|$
- $C_{\text{par}} = \left|\frac{I_{\text{cappar}}}{10\,\text{MHz}\cdot VDDA_{\text{capmeas}}}\right|$
  - I_{capmeas} from IMUX(10)
  - I_{cappar} from IMUX(11)
  - $VDDA_{\text{capmeas}}$ from VMUX(4): VDDA/2 from capmeasure
- $\Delta C = 0.48\,\text{fF}$ obtaind from layout extraction.

Reason for ΔC: