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Software for silicon Quality Assurance program for CDF Run2b silicon detector.

D. Naumov, M. Hoeferkamp, S. Seidel, I. Gorelov.
University of New Mexico, Albuquerque, USA

Abstract

This document contains a basic description of the software package for automated measurements of silicon sensors characteristics, developed in frames of Run2b silicon detectors Quality Assurance program, and also a description of appropriate tests.

1. Introduction

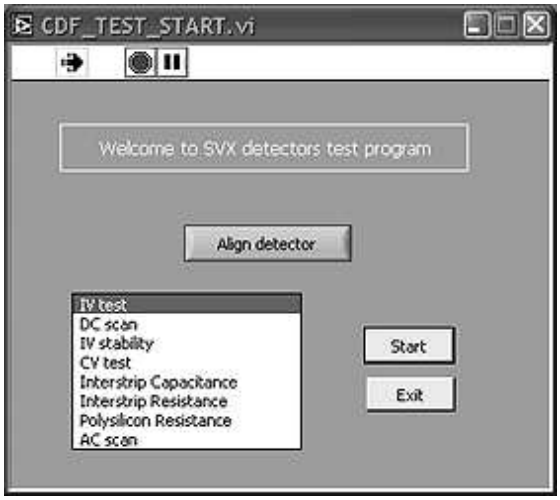
CDF collaboration organized a quality assurance (QA) program for a new silicon tracker system for Tevatron collider. New silicon system is expected to become operational in 2005, and will replace the existing L00 and SVXII detectors.

The success of the new silicon detector depends on an efficient silicon sensor probing and characterization. Several institutes, which have been certified by the Run2b silicon group, are participating in this program, sharing different tasks of a complex QA test. In frames of quality assurance program, workgroup at University of New Mexico has developed a measurements automation software package, designed specially for silicon sensors testing, using "Alessi" automatic probstation and appropriate number of electrometers and LCR meters. Created QA software package contains **more then 150** code modules and device drivers. This document basically describes the software and appropriate tests.

2. Overview

Above-mentioned software were realized using LabView 6.1 which is a powerful graphical development environment for signal acquisition, measurement analysis, and data presentation, and could give the flexibility of a data flowing programming language without the complexity of traditional development tools.

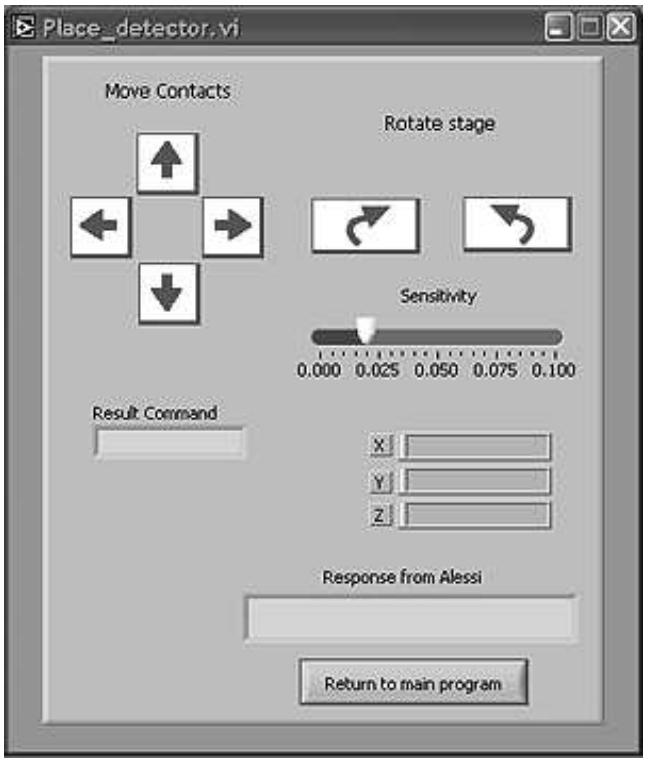
That has simplified an interaction of the application with all the electronic devices used in task, which took place through standard PCI-GPIB interface, IEEE-488 bus and Device Dependent Command protocol (DDC) (in case of Keithley electrometers and HP LCR meters) and through Dynamic Data Exchange communications protocol for operating Alessi automatic probstation.



Pic 2.1 "test starting window"

As base for development it was taken a framework written by Grant Gorfine for not automated measurements (in other experiment). Testing application consists of 8 tests. 2 Tests (IV and CV) are Grant Gorfine's and all other are include some initial code elements, but then are about 70 - 90% upgraded or modified by Dmitriy Naumov. On picture 2.1 you can see test starting window, from which you can open Chuck Alignment Module and execute each test. Also Dmitriy Naumov has developed several useful addons for data operation simplification, debugging modules and drivers for measurement devices which Grant Gorfine's software could not operate (such as new versions of LCR meters and Alessi Probing Station itself).

Chuck Alignment Module is example of measurement station debugging module. It initially sets clearance intervals and lets program or operator move chuck safely, excluding accidental sensor damage. It also generates appropriate DDC commands and indicates a response from Alessi probing station. One can adjust sensitivity, i.e. chuck movement speed. On the picture 2.2 you see how this window look like.



Pic 2.2 "Chuck Alignment"

3. Tests Performed

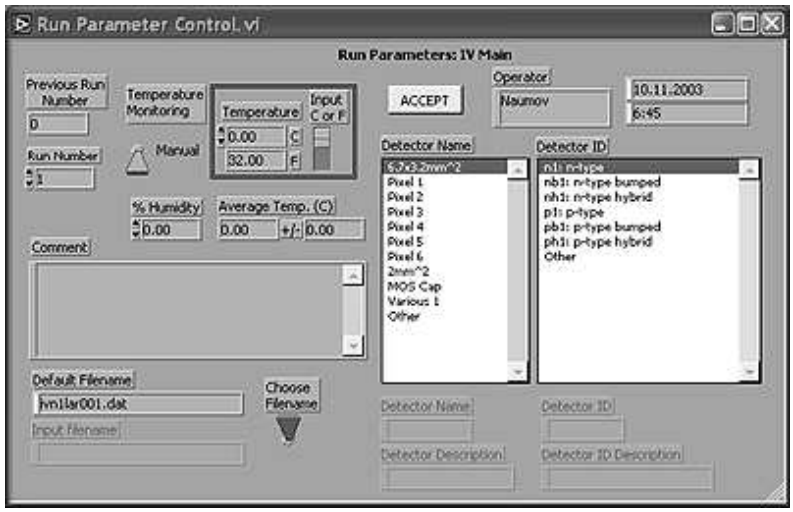
Below you can see a list of performed tests and amount of time needed to proceed with each test. First 3 tests are main, for all sensors. And other 5 are diagnostic, in case if first 3 will determine some manufacturer defects.

- I-V, 15 minutes
- AC Scan, 5 Hours average, depending on delay settings
- C-V, 15 minutes

- DC Scan, 1.5 Hours
- Polysilicon Resistor, 2 hours
- Interstrip Capacitance, 2 Hours

• Interstrip Resistance, 2 Hours
• IV Stability, 10 Hours

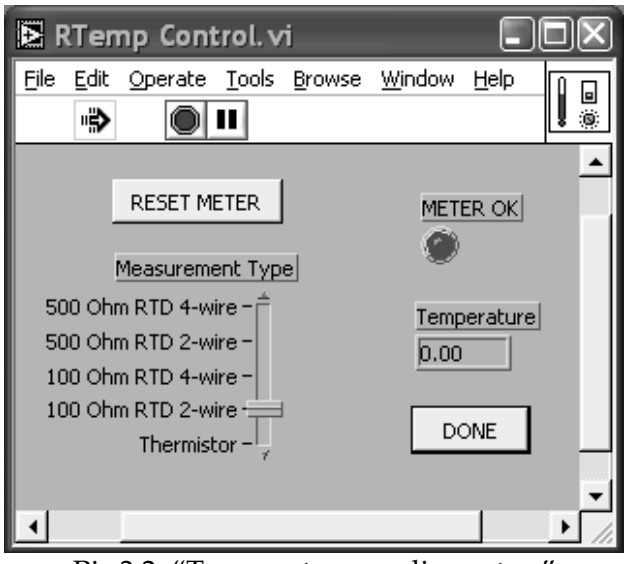
Each test has “run parameter control” window to set common initial parameters, such as results file name, run number, run date and operator’s name.



Pic 3.1 “Run Parameter Control”

Filename for saving data can be set by user of automatically generated from run parameters data. Each test has a unique number with located in files *.num in Run_numbers directory.

Temperature is measured using thermo-pair. In “Rtemp Control” window one can select measurement type:

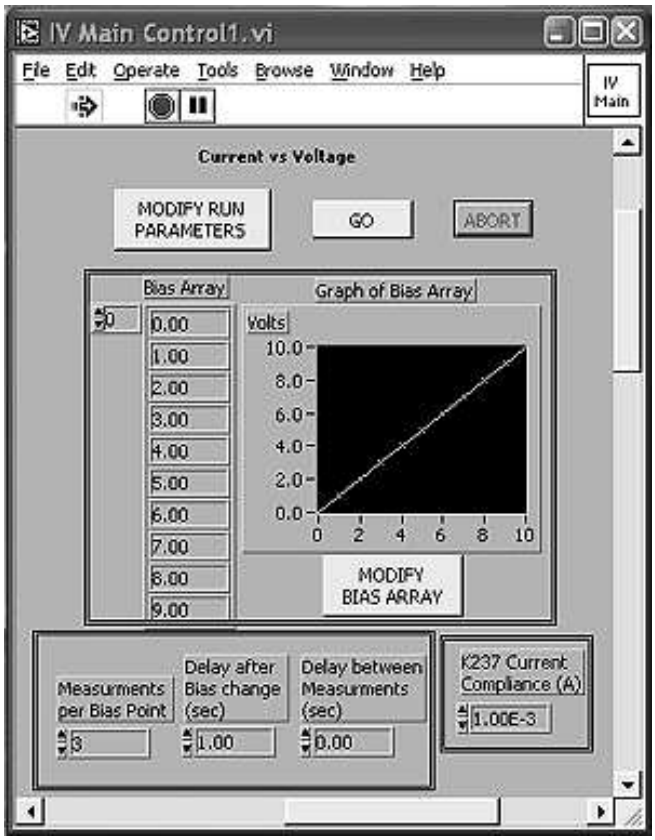


Pic 3.2 “Temperature reading setup”

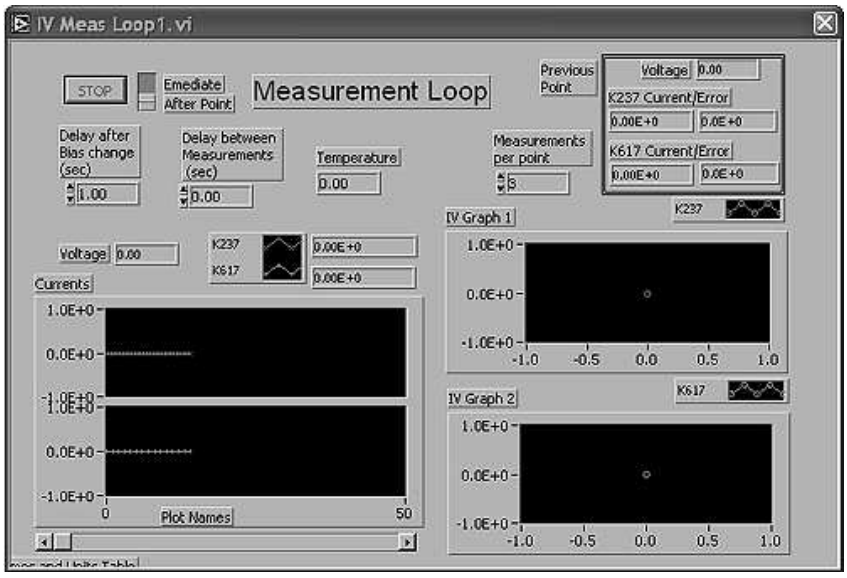
4. IV Curve (leakage current determination)

This is one of the main measurements, and is carried out for every sensor. Detector is placed on a probstation's wafer and probe needle is put on the bias ring (see scheme) to measure I-V characteristic between the backside and bias ring: Bias voltage steps from 0V up to 1000 volts, with 10V step and current is measured each time. Compliance current should be set to 50 micro amperes, and probstation environment temperature recorded. Each step 3 measurements are made and the result is mean value, and errors usually are calculated as standard derivation. All run parameters, currents and voltages are saved into file at the end of the test.

Measurement parameters, such as bias voltage, delays and Compliance current for each test one can set it appropriate Main Control window.



Pic 4.1 "Main Control window for IV test"



Pic 4.2 "Measurement Loop window"

During the measurement, in Measurement Loop window one can observe graphs of measured parameter realtime.

5. CV Curve

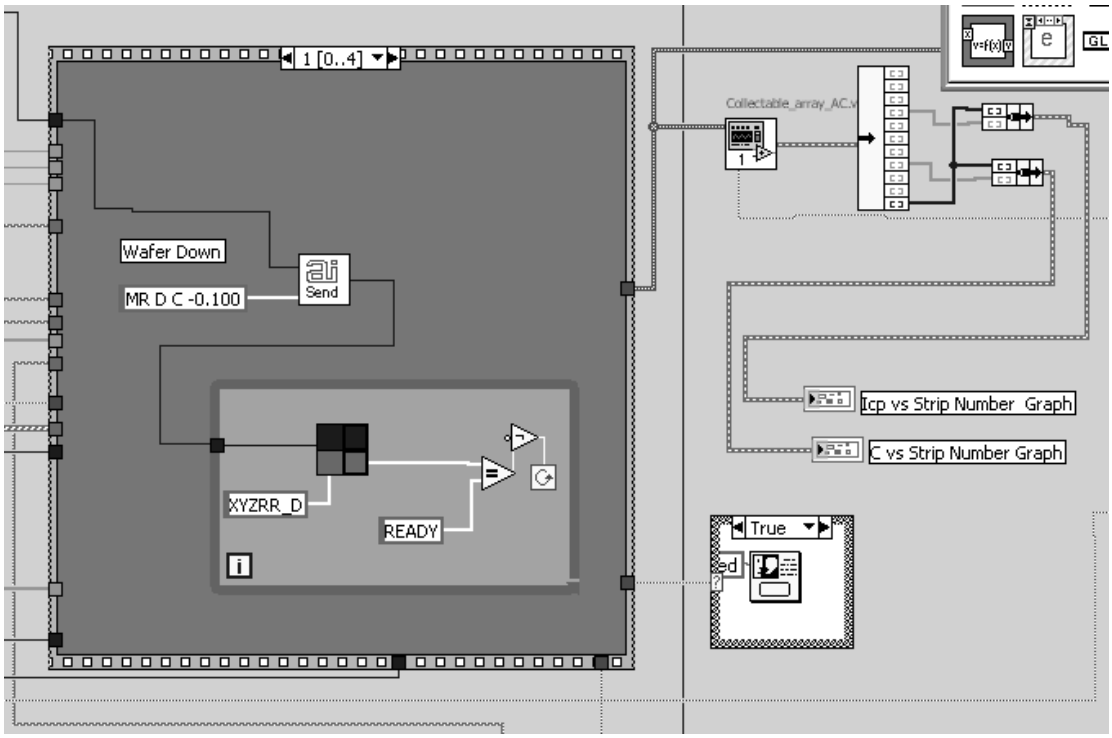
The electrical scheme to measure the total capacitance is shown below. Bias ring and Nsub probes are connected to L and H of LCR meter through capacitors of 1 micro farads. LCR frequency has to be as low as 100Hz in this configuration. Capacitance is measuring, while bias voltage steps up to 500V with 10v steps. The full depletion voltage is defined as the intersection of two straight lines when data is plotted in 1/C^2 vs. V bias.

6. AC Scan (full strip test)

This is the most comprehensive test in the package. In order to evaluate the coupling capacitance, the uniformity of the polysilicon resistances, and to check pinholes in capacitor dielectric, it probes the AC pad of every strip. It should include elements of both previous tests, so the development was based on CV test with including some code parts from IV test.

Main challenge during AC scan implementation was to automate measurements, so one could not put needle probs on every of 1024

strips of the detector by hands. For that needs an “invisible” (placing no VI’s on the screen) before Loop Control subprogram was modified into “AC Meas Loop Control.vi” and included wafer movement elements and data collecting elements.



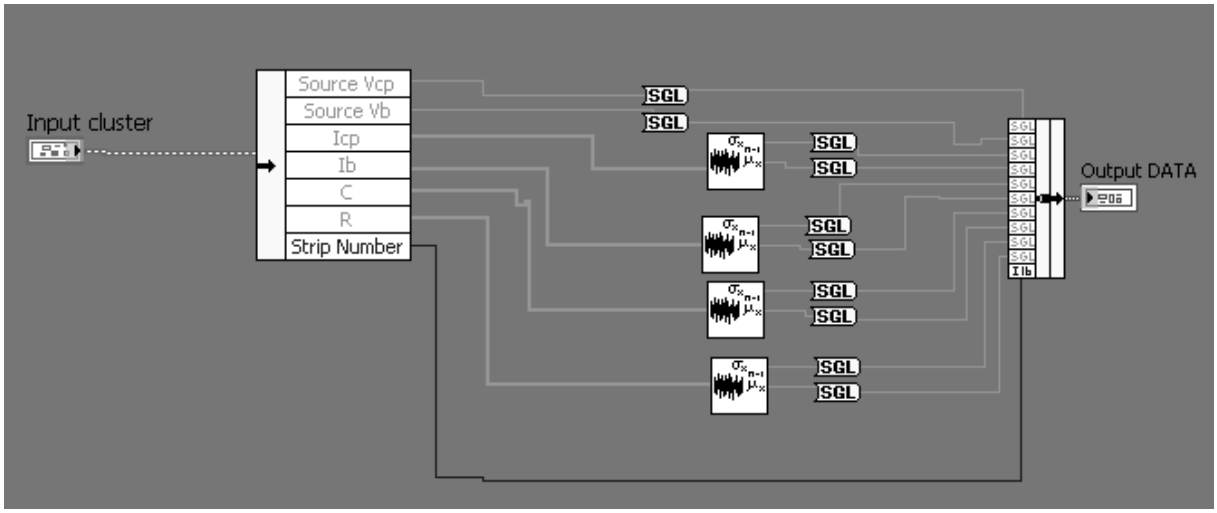
Pic 6.1 “Main Loop Control code fragment”

For placing needles to the next strip, wafer platform moves down (preventing sensor damage), then moves to the next strip and then moves up again. On the pic. 6.1 you can see procedure of sending “wafer down” command signal and control of response.

Meas Loop subprogram was modified into “AC Meas Loop.vi” for ramping source voltages and proceeding with number of measurements for particular strip. Then it return this data to Loop Control subprogram.

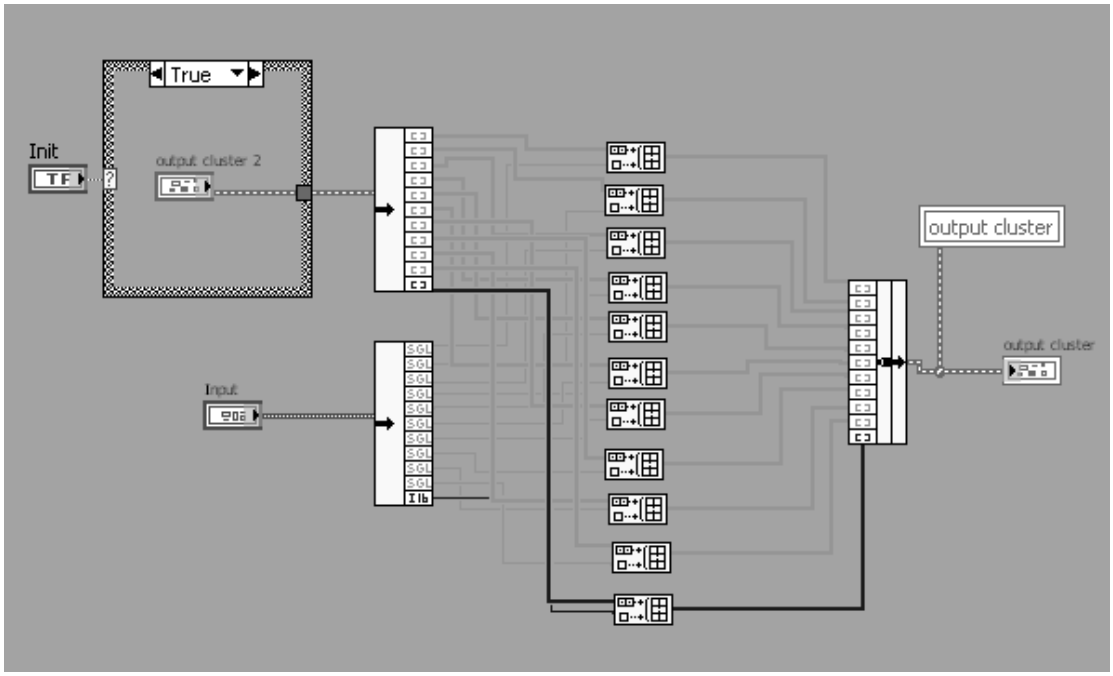
The test requires 2 different voltage sources: Vbias (to deplete sensor) and Vcp. During measurements, Alessi automatic probestation moves needle contacts relative over all the readouts on AC pad (A, first needle), and on bias ring (B, second needle). And bias voltage is provided via contacting the backside.

One of the added modules is “Pack Values” for error calculation and forming measured data array, suitable for saving. It is used also in other tests.

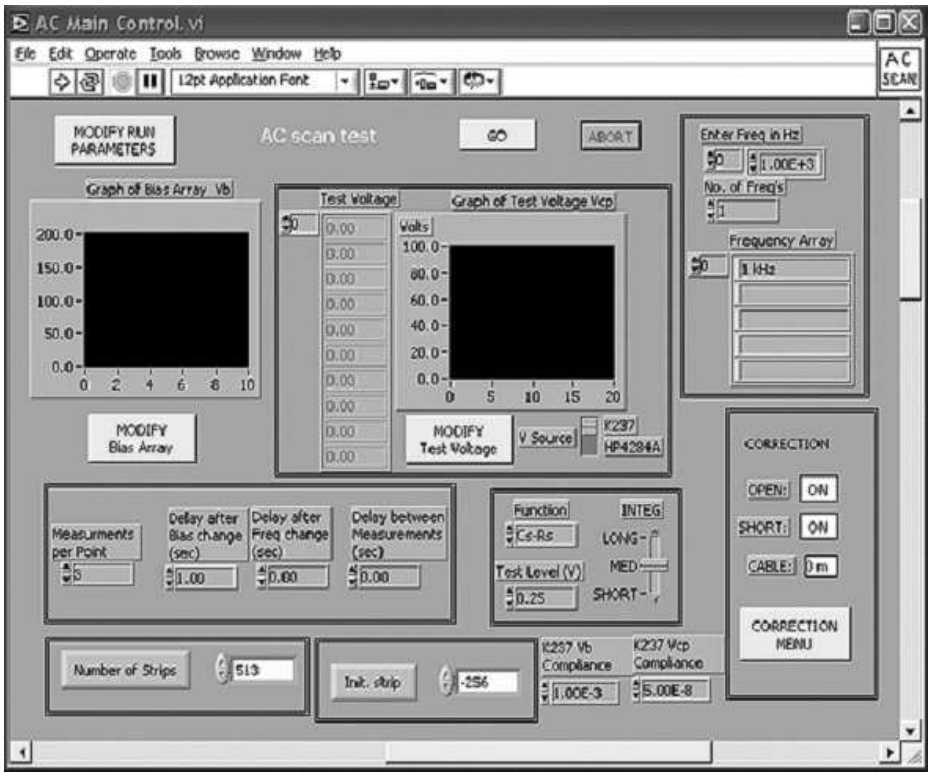


Pic 6.2 “Pack Values” addon code.

LabView is a data-flowing language. That means that variable values come through wires, and when new one is coming, - the previous one will be replaced. For online monitoring of measured data amount a growing array of data clusters was needed. LabView does not include such type of arrays, so it was implemented in program module called “Collectible Array” and used in several tests.

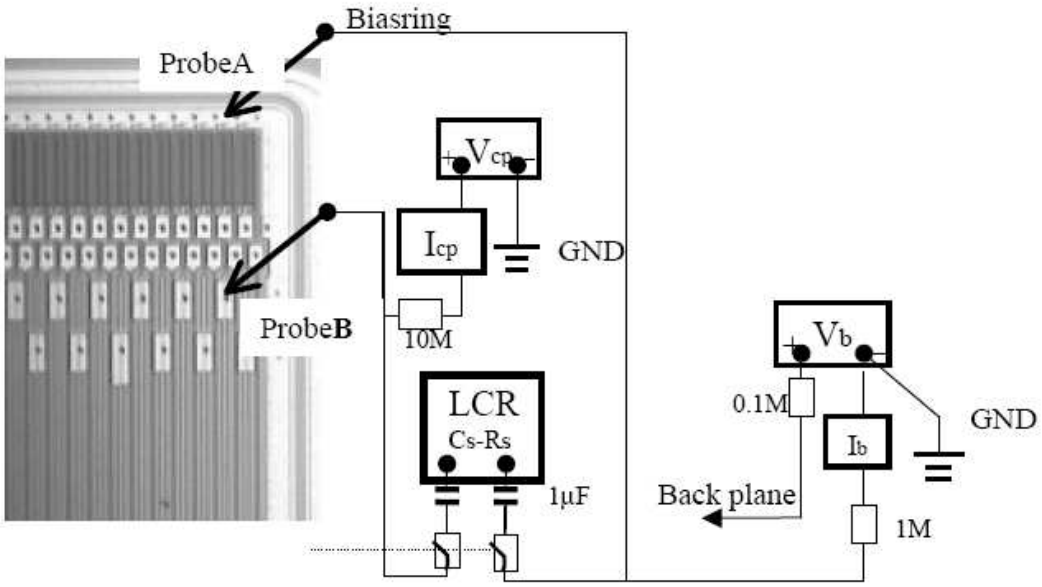


Pic 6.3 “Collectible Array” code.



Pic 6.4 "Main Control window for AC - Scan test"

After Naumov's upgrade, the data saving modules obtained meaningful simplification! Even less experienced LabView developer can now easily understand that part of the program from the first look and modify data saving format for his (her) needs.



Pic 6.5 "AC - Scan test experimental setup"

Measurement algorithm:

- Ramp up the V bias to operation value.
- Move probes to the strip N and contact both needles (A and B)
- Increase test voltage Vcp to 10V, wait 1 sec, and check if compliance is reached. (current limit is 50 micro amperes). If it is not reached – program goes further, otherwise it skips next step.
- Increase Vcp to 100V, wait 1 sec and measure the current.
- Decrease the test voltage Vcp to 0V and operate Switch "ON".
- Measure C and R at 1kHz in Cs-Rs mode , and operate Switch "OFF"
- Move probes to strip N+1 and repeat measurements from the third step of this algorithm.

7. DC Scan (strip leakage current)

If IV test shows unusually large currents, or IV curve stability test gives unstable results, DC scan test should be performed. It is the opportunity to find the current leakage source. The test development was based on IV's skeleton. As the AC Scan, DC Scan is also automated test and is using the most of addons described in previous chapter.

Measurement algorithm:

- Ramp up the V bias to operation value.
- Move probes to contact the DC pad and the biasring.
- Measure the bias current Ib, which should be consistent with the known value. (otherwise check contacts)
- If previous step is ok, then measure strip current Istrip.
- Move to next strip to measure and repeat measurement cycle.
- Ramp down the bias voltage to 0V.

8. Polysilicon Resistance

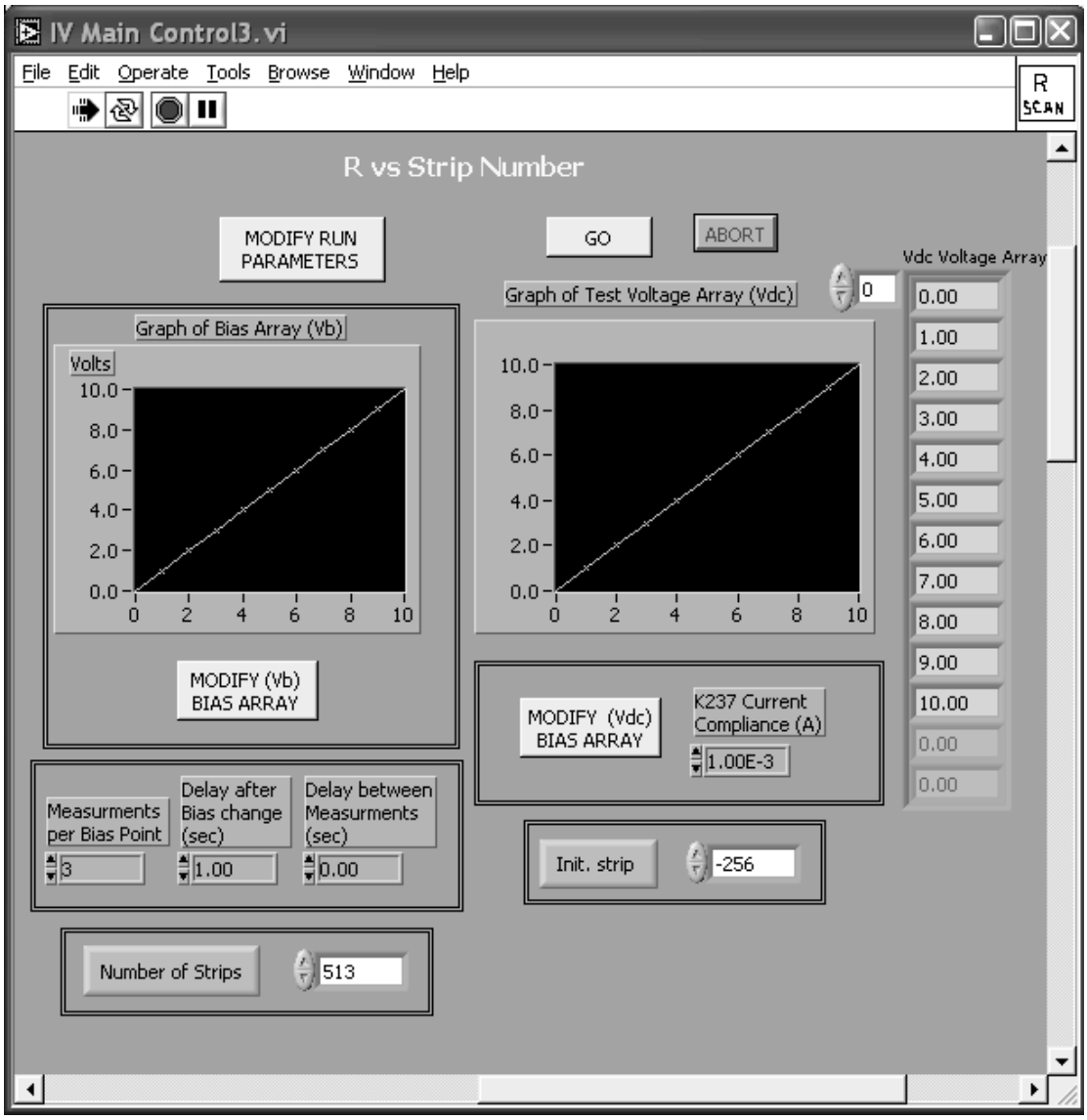
If sensor shows irregular value of R after AC scan test, it is subject to check the polysilicon resistance. It is recommended to proceed this test on the same frequency as the AC scan. The resistance is evaluated by probing DC pad and biasring, and by measuring resistance by LCR meter. Recommended voltage for fully deplete is 200V. Neighbour strips should be measured as well for comparison. Acceptance criteria for polysilicon resistor values is:
"within 1.5 +/- 0.5 Mohms"

9. Interstrip Capacitance

This test is measurement the capacitance from one strip to neighbour strips, and from one strip to the backplane, which is main contribution to the total capacitance. Biasring of the detector is connected to the grounded-low side of the voltage source, and the backplane is connected to high side of it. Ramp the bias voltage Vb and place 2 probe needles on the AC pads. Capacitance value is measuring at frequency 1MHz. Measurement is proceeding over all the strips (AC pad). The acceptance criteria for the capacitance is "to be less then 11.2 pico farads"

10. Interstrip Resistance

Interstrip resistance is determined by measuring the induced currents while applying voltages to the neighboring intermediate strips. Probe needles contacted to a voltage source added to the strip leak current measurement system.



Pic 10.1 "Main Control window for IR - Scan test"

As it is needed for hardware (electric scheme) setup for this test, dual source voltages array was created in Main Control module. User can separately set Bias Voltage and Test Voltage in this application. Interstrip resistance can be measured for any number of strips.

Measurement algorithm:

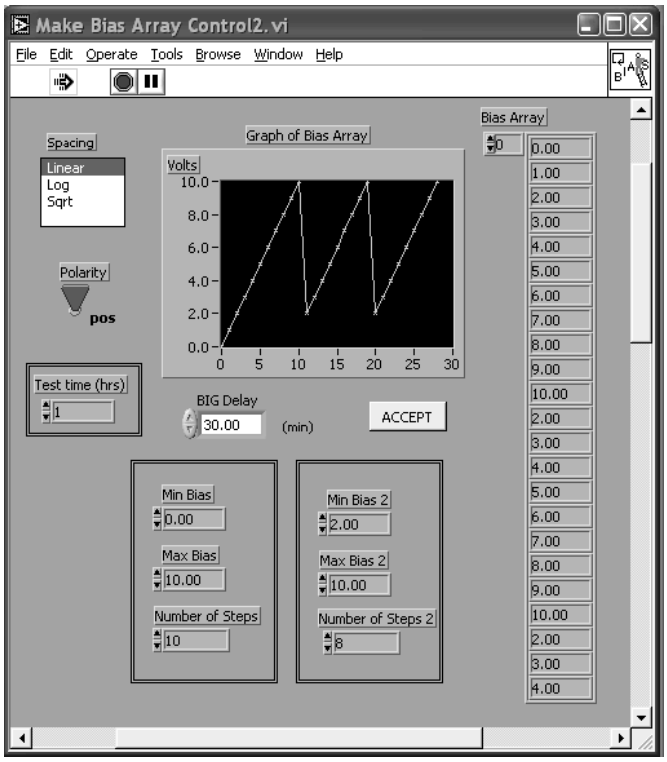
- Ramp up the V bias to operation value.
- Set the testing voltage Vdc from –1V to +1V with 0.5V step.
- Wait 1sec and read strip current Idc.
- Calculate value of interstrip resistance: R = dV/dI

Where dV=2V, and dI = I(+1V) – I (-1V)

- Repeat from step 2 for all the strips.

11. IV Curve Stability test

This test should check if a leakage current characteristics over a 10 hour period are consistent and small. Bias voltage in this test steps up to 1000 volts as it was described in IV test. After this measurements , bias voltage is set to operation voltage (200V) and 30 minutes delay is performed. Then bias voltage steps up to 1000 volts again, and these cycles are continue over 10 hours. After correction of the temperature variation, the leakage current should be constant to 20%.



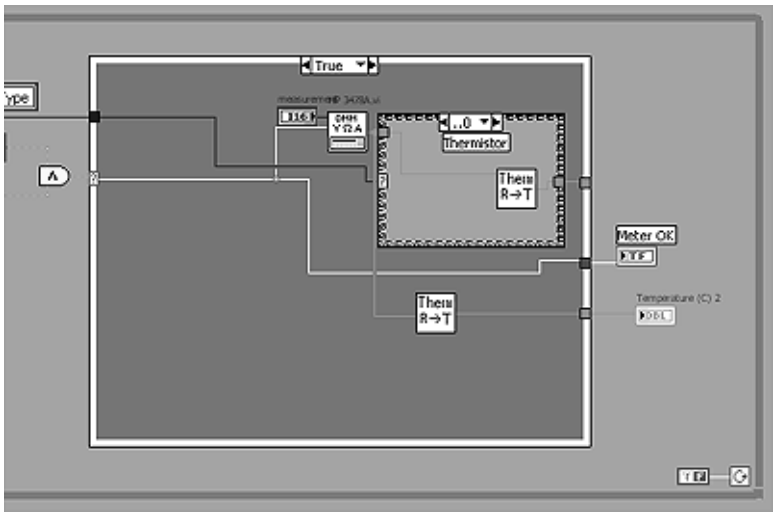
Pic 11.1 "IV Curve Stability bias voltage generation window"

One of the tasks in this test development was to generate a complex bias voltage array, ramping voltage down and repeating ramping it up. That task was successfully completed, so all the curve is now controlled with 2 parameters: Total test time and BIG Delay setting. Generated numeric array one can see in right column on pic 11.1

12. Software "inside".

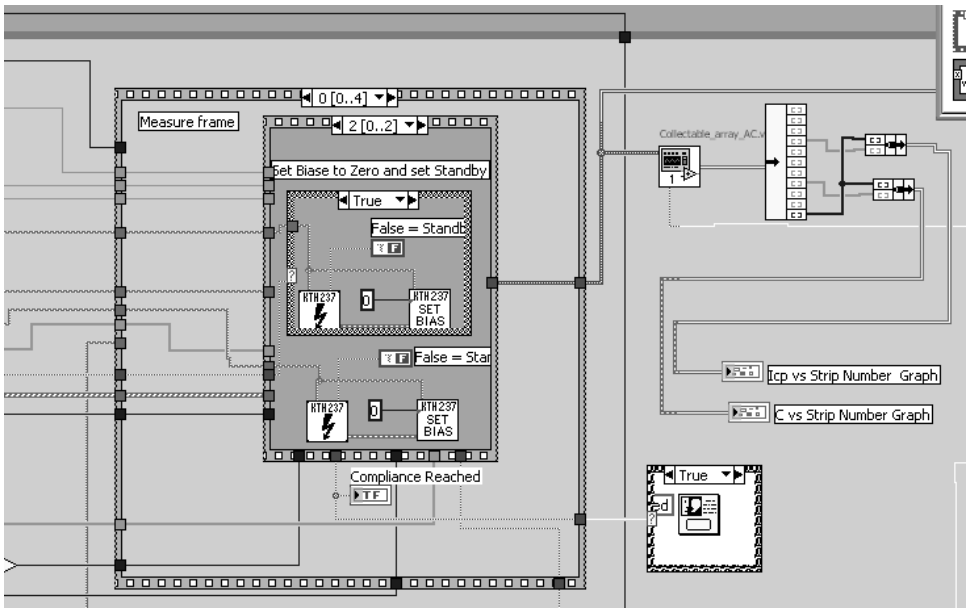
LabView is data flowing programming language, that differs it from all other application development environments, such as object oriented C++, etc. It was created to implement real time applications, mostly for

the case when it is needed to connect a PC with various hardware and control its work programmically. A source code of LabView application looks like a micro scheme, with wires connected to Visual Instruments (VI's).



Pic 12.1 "Temperature reading driver for LCR HP-3478A (fragment)."

One of noticeable disadvantages of LabView applications is strong CPU usage. But it is necessary because application pretend to be realtime data acquirement system, so for maximum productivity it should take the most of processor time. So it's possible that some applications, working parallel with it, on the same PC may "feel uncomfortable". The solution is simple. LabView supports net data transferring protocols, so any software could communicate with it through local (intra) or internet.



Pic 12.2 "Code example {AC Measurement Loop Control Module} (fragment)."

13. Conclusion

In frames of CDF Run2b Quality Assurance program, algorithms for fully automated characterization of many-channel systems were designed, and control software package was developed to implement all required tests. During software design also were developed drivers for various electrometers and LCR meters used in task.

This project was initially motivated by the CDF Run 2b silicon upgrade but can be generalized to structures on other substrates and devices for other high radiation environment applications.