QA/QC FOR MODULE PRODUCTION

1 INTRODUCTION

This document describes the module production, quality assurance and quality control measures for a new Layer 0 silicon detector that will be employed to ensure that high-quality modules are produced with a minimum of loss, or repair effort, associated with processing steps at Fermilab. The Layer 0 silicon detector has a 6-fold geometry and consists of 48 modules of 8 different types. We plan to produces 8 modules of each type. Six modules will be selected after rigorous testing for the Layer 0 detector assembly.

It is well understood that handling issues need to be continually assessed during the design and development of assembly tooling and personnel experienced in hands-on silicon detector assembly (physicists, engineers and technicians) are an integral part of the design team developing the tooling and procedures. Furthermore procedures and testing must be in place to quickly identify processing issues during production. This is particularly true in Run IIb where the time frame is short and the daily production rate is high. A failure to catch a processing problem for two weeks could result in the loss of roughly 10% of the detector modules. In order to alleviate this risk the procedures outlined below provide for testing of all parts immediately after all significant handling steps, with a lag of less than five days from the start of that handling step. At any time that one suspects a processing problem there is the possibility of an immediate electrical test. However, the main concern is a systematic source of damage that goes unnoticed.

Prior to the start of module production phase there will be a production readiness review requiring the approval of the L2 managers for proceeding with the production. This will include a review of the written procedures and documentation to aid the assembly (e.g. assembly drawings, travelers etc.) and a list of the trained staff with the lead technician and responsible floor manager clearly identified.

All electrical tests described in this document are performed with the PC based Saseq Test stands described in [1].

2 MODULE PRODUCTION FLOW OVERVIEW

This section provides a description of the L0 module production. Layer 0 module consists of sensor, laminated with kapton wrap-around circuit, pitch adapter mounted on the sensor, analog cable assembly wire bonded to the pitch adapter on the sensor side and to the SVX 4 chip mounted on beryllium substrate hybrid on the other end. Schematic diagram of Layer 0 module is shown on Figure 1. More details can be found in the Technical Design Report [2]. All the parts, except hybrids, were received from vendors and currently are stored at SiDet and ready for module production. Hybrids are stuffed at NXGen, and after testing and QA procedures [3] at California State University at Fresno and University of Kansas (KU) will be shipped to Fermilab. The following preparatory steps are necessary before module assembly begins:

- Hybrids will undergo a quick functionality test upon receiving them from KU, to make sure that no damage occurred during shipment.
- Bonds on the back-end of the SVX4 chip will be encapsulated, to reduce the risk of damaging them.
- Hybrids will be tested in short 24-hour burn-in run to ensure that no damage was done during encapsulation
- Only the highest quality hybrids, with uniform pedestal, noise, gain distributions and no read out errors will be selected for the Layer 0 module assembly. Information about the depletion voltage and the number of bad strips will be provided as input to the testing and assembly group and taken into account when choosing sensors for a particular detector module. The hybrids and sensors will already have undergone their QA/QC procedures and only "certified" parts will be used for assembly of modules.
- Hybrid, sensor, analog cable necessary for module assembly of given type will be identified and entered into database.
- Module traveler will be produced based on the record in the database. In addition all the information from the hybrid and sensor associated with particular module will be inserted in the module traveler and kept for future reference.

The sequence for the production, assembly and testing of modules includes the following steps:

1. Parts selection according to particular module traveler.
2. Module assembly
3. Initial functionality test
4. Long term burn-in test

3 MODULE ASSEMBLY PROCEDURE

The schedule below describes the assembly procedures that will be used. These assembly techniques were designed and used during production of 10 modules for the Layer 0 electrical prototype. The flow of the assembly procedure is shown schematically on Figure 1 and includes the following steps:

1. Sensor is glued to kapton wrap around circuit, and spacers (substructure) to top cable.
2. Bottom, cable is glued to the hybrid and pitch adapter.
3. SVX chip is wire bonded to the bottom cable.
4. The top cable is glued to the bottom cable. Wrapping of the sensor is completed.
5. Pitch adapter is glued to the sensor.
6. Analog cables are wire boned to the pitch adapter and SVX chip
7. Sensor is bonded to pitch adapter.

Initially, we plan to produce 4 modules per week. This schedule is conservative and relies only on existing tooling. When additional fixtures become available the production rate can be increased to 8 modules per week. All modules should undergo full functionality tests within 4 days of the start of assembly.

Day 1: Top and bottom analog cables and sensor are prepared for assembly. Ceramic spacers are glued on top analog cable. Bottom cable is glued on to pitch adapter on one end and on to hybrid on the other end. In a separate procedure the sensor is glued onto kapton wrap around circuit.

The specific hybrid, cable and pitch adapter assembly procedures are (steps 1 and 2 from the assembly flow list on page 2 and Figure 1):

1. Select appropriate hybrid, pitch adapter and cable length (top and bottom) per traveler.
2. Mask cables with 0.002" kapton tape flush to each end of cables top and bottom.

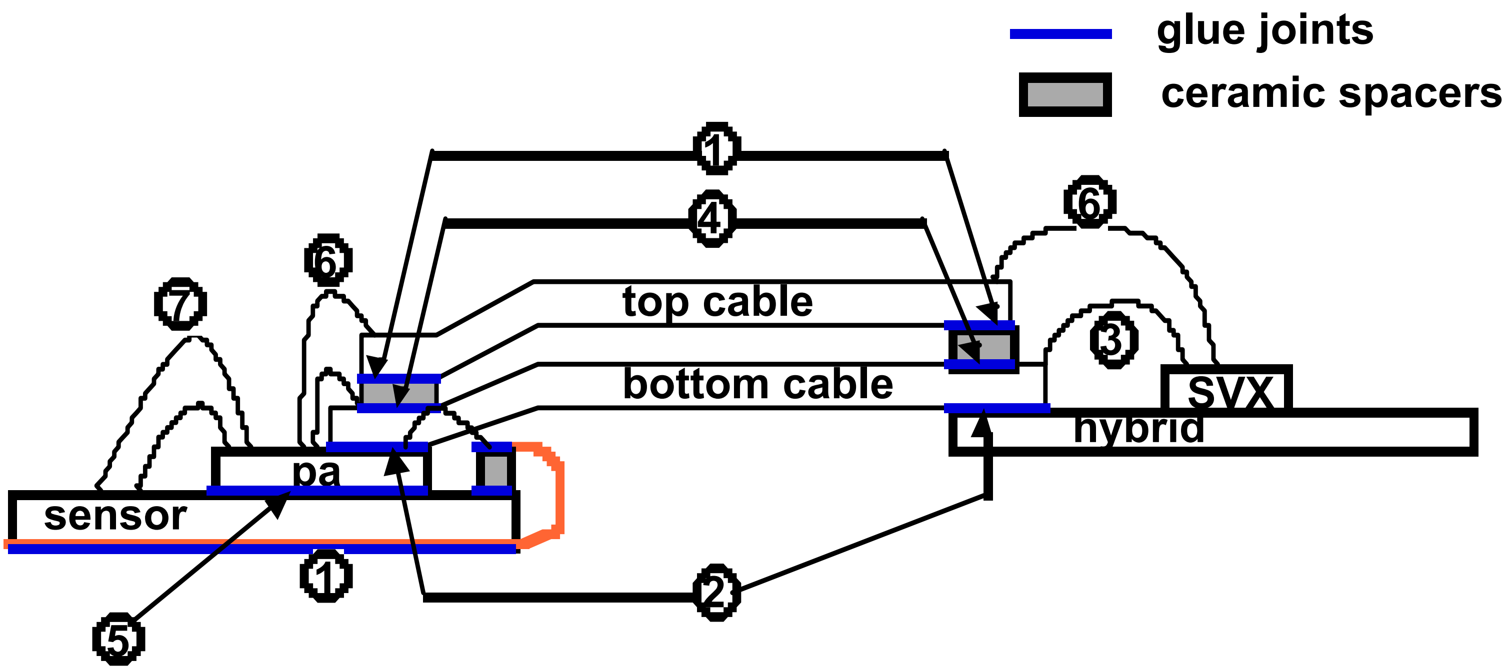

Figure 1: Steps in the Layer 0 module assembly.

3. Select the appropriate substructures (hybrid end is wider) for top cables.
4. Place the correct pitch adapter into fixture
5. Mask pitch adapter at 2 locations (H.V and I/O bonds) carefully, not to overlap the contact area
6. Place hybrid against alignment pins.
7. Mix TDR1100 epoxy (10g resin to 4.2 g hardener). Mix for 3 minutes and then transfer into 10 cc syringe and centrifuge for 4 minutes.
8. Select a red tip 0.010" inner diameter, set station at 60 psi.
9. Carefully lift top cables and run a bead of epoxy along the center of the substructure. For bottom cable, run a bead inboard 1 mm from bond pads on pitch adapter and add one extra drop at H.V. and ground pads. Run a bead inboard 1 mm from bond pads on hybrid and add one extra drop at H.V. and ground pads.
10. Place T-plate with brass weights accordingly and block weight on hybrid.

11. Verify all contacts are good and there is not any excess epoxy migrating, wipe if necessary.

The specific sensor assembly procedures are:

1. Select appropriate sensor, wrap circuit and wrap substructure per traveler.
2. Set up circuit and substructure in appropriate fixtures. Circuit faces up with round pad to the left and substructure aligns to edge of placement fixture.
3. Place sensor in into alignment fixture with bond pads to the left.
4. Pick up sensor and locate over circuit.
5. Verify alignment along the width to be 500 μm from kapton cut edge and at the right end where the L marks for x-axis alignment right on the mark.
6. Once alignment is set remove sensor to the side.
7. Mask off kapton circuit epoxy area 4 mm inboard of sensor contact area along with round ground pad with 50 μm kapton.
8. Mix epoxy (TDR1100- 10g resin to 4.2 g hardener, centrifuge). Use tapered blue tip to dispense and then slide a razor blade across the epoxy to spread to a 50 μm film. Remove masks. Apply 2902 tra-con silver to round pad.
9. Place sensor onto prepared circuit.
10. Run a line of epoxy along the center of the wrap substructure while in the pick up fixture. Then place onto wrap circuit.
11. Place a weight across both placement fixtures.

Day 2: At this time bottom cable is bonded to SVX chip and top cable glued to bottom cable.

The specific hybrid, cable and pitch adapter assembly procedures are (steps 3 and 4 from the assembly flow list on page 2 and Figure 1):

1. Remove masking from all components.
2. Transfer hybrid, pitch adapter and cable to 8090 bonder. Complete hybrid to bottom cable bonds (inner bonds) along with H.V. and ground bonds.
3. Visually inspect bonds. Record channel number for all shorted and disconnected bonds in the bonding checklist. Repeat bonding procedure as necessary.
4. Stage 1 bonding is complete. Return to assembly fixture.
5. Locate correct mesh spacer and trim 1 mm from solid end and place on top of bottom assembly.
6. Remove top cable from fixture and lay cable traces down on a soft nonmetal surface. Inspect underside of substructure and remove any epoxy that may have migrated under due to vacuum.
7. Locate top cable onto bottom assembly carefully not to bump bonds.
8. Repeat glue-mixing process (change tip to clear 0.008” inner diameter).
9. Use a q-tip to lift top cable up and expose underside substructure. Apply three drops of epoxy at mesh end and also along the center of the substructure at each end. Then set down cable carefully and apply weight. The masks are removed at this point and it is essential that epoxy does not migrate onto bond pads.

The specific sensor assembly procedures are:

1. Remove weights from fixtures, turn off vacuum and remove placement fixtures.
2. Trim kapton with scalpel at tabs along cut slots and carefully at the wrap end and remove from fixture.
3. Locate wrap fixture and place sensor into it
4. Place optical paper onto sensor in order to protect sensor from scratching when bending the wrap onto the sensor.
5. Place a weight onto wrap to conform and constrain into place.
6. Mix epoxy. Use the red tip with 0.010" I.D. at 60 psi.
7. Remove weight and apply a line of epoxy along the center of the structure inboard 2 mm from ends in order to keep epoxy from filleting onto outer edges of the substructure.

At this point new set of modules can be started, following the procedures from the day 1.

Day 3: Pitch adaptor from the hybrid and analog cable assembly is glued onto the sensor (step 5 from the assembly flow list on page 2 and Figure 1). In a prototyped assembly procedure pitch adapter is located and aligned manually on the sensor with the optical feedback. This process can be improved and sped up if special type of fixture with alignment pins is used. Currently there is a provision to produce that fixture and it should be ready before the start of module production.

Day 4: Wire bonding will be done first between the top and bottom analog cable to the pitch adapter. Then assembly needs to be rotated manually to perform wire bonding between the SVX to the top analog cable (outer bonds). Finally bonding is performed between sensor and pitch adaptor (steps 6 and 7 from the assembly flow list on page 2 and Figure 1). After each bonding step bonds will be visually inspected and shorted or disconnected bonds will be recorded in traveler. Bonding procedure will be repeated if necessary. We plan to reduce manual handling of the module to avoid accidental damage. This can be achieved by using special bonding fixture, which represent a metal plate that can accommodate all 4 analog cable lengths and has a special vacuum locks to hold the assembly.

At this point the modules are ready for testing. Malfunctioning modules will be sent to the repair team for diagnosis and repair. Any systematic problems will immediately trigger a cessation of the production until the source of the problem is identified and a remedy found. Any such stoppage will require another readiness review with L2 management approval prior to resuming production.

4 MODULE TESTING

Modules will be electrically tested only after the final assembly, repeating the short functionality test described in the QA document for hybrids. In order to be able to read out the hybrid, a short digital jumper cable (testing cable) needs to be connected to the module. This will be done after assembly and wire bonding of the detector module. The connection of this testing cable needs to be done by a skilled technician, as it is a delicate operation that takes place with exposed wire bonds. The testing cable will remain attached to the module during the complete testing process until the module is installed in the tracker and the final jumper cable is connected. The cables used will be tested before being attached to a module. Once a module has been assembled, wire bonded, and a testing cable has been connected, it will be stored in boxes either built for the Run IIb project or slightly modified to accommodate modules with longer analog cables. These boxes allow for electrical testing, providing a path out of the box for the digital readout cable and a light-tight seal to allow biasing of the sensors. A copper finger pressing against the ground pad on the hybrid and screwed to the base plate of the box provides the grounding of the module. In addition, a short copper braid connects the finger to the box lid. The modules will remain in these boxes through testing and burn-in and will only be removed when they are to be installed on the staves. Connecting the testing cable to the purple card, without opening the storage box, can electrically test modules.

4.1 Debugging of Detector Modules

Immediately after a detector module is produced, and before it is burned-in, it needs to undergo a functionality test, that we call "debugging". The likelihood of damaging the detector modules during construction, in particular during wire bonding, is not negligible. An intermediate step between production and before module burn-in is needed to restore the functionality of the modules before performing any electrical tests. The steps we plan to follow during the debugging process are the following.

- Visual Inspection: A thorough visual inspection of the finished module will ensure that no mistakes were made during wire bonding and no mechanical damage occurred. Any anomalies, like cases of two-step bonding, scratches etc. will be reported in the module traveler together with the IDs of the affected channels.
- Functionality test: this test is done on the module without applying bias voltage to the sensor to assure the electrical integrity of the hybrid after module production.
- Biasing of the detector: bias voltage is applied in 5V increments, monitoring the leakage current. Capacitors that might be broken during wire bonding will be identified during this step. Strips corresponding to broken capacitors will be disconnected from the readout electronics by pulling the wire bond between the silicon sensor AC bonding pad and the pitch adapter.
- Characterize the module by producing V-I curves. The operational voltage for all modules is expected to be 200V and the V-I curves will cover the bias voltage range of 0 to 300V. The procedure to obtain V-I curves has been automated using the Lab-View software.

We have two 1-Saseq debugging stations in the SiDet burn-in room to check out modules as soon as they have been completed. The functionality test for an average module takes less than an hour, unless problems occur that require a thorough investigation. However, there is an ample time to work on modules that might have been damaged during production and may require several iterations of the functionality test. The results of the tests are stored in traveler. They are also accessible through the module testing web page.

4.2 Burn-in Tests for hybrids and detector modules

The burn-in test is part and parcel of the testing procedure for module production. It will be performed first on the stuffed hybrid after it has passed the initial functionality test described above. At this point the hybrids are subjected to long-term readout cycles. The goal of the test is to select good hybrids for module assembly. The hybrid burn-in test will be done in two stages. After the initial burn-in test of duration less than 12 hours, hybrids passing our quality criteria will be encapsulated and subjected to a second, 24 hour long, burn in test. The final burn-in test will be carried out after a module has been produced and it has passed the initial functionality test. The idea of the burn-in test is to run every component for a long period of time (up to 72 hours) under conditions similar to those expected in the experiment (bias voltage of 200V) and monitor its performance, in particular, measure pedestals, total noise, random noise and gain and examine occupancy in sparse readout mode. Other parameters that will be monitored include temperature, chip current, and detector bias voltage and dark current measurement (in module burn-in only). Typical problems that are revealed by the burn-in tests are SVX chip failures, broken and shorted bonds, grounding problems, noisy strips and coupling capacitor failures.

There are two hybrid/module burn-in stations available, with a capacity of 16 channels each. This gives us more than adequate burn-in capacity to accommodate an anticipated production rate of about 8 modules per week. We are using the Run IIa burn-in software, modified for our new modules. The Run IIa software was based on a user-friendly Graphical User Interface written in the TCL/TK scripting language with the graphical toolkit in the Windows environment. This choice of software interface created a flexible system for performing a variety of tests using executables written in different programming languages, for data taking, monitoring and data analysis. The software is sufficiently user friendly to be used by non-expert physicists, taking ``burn-in'' shifts, if necessary. The summary plots are stored and available on the web. An EXCEL based template will be used for extracting parameters characterizing module performance and its evaluation. A printed version of it will be added to the module traveler. A trained physicist will do the evaluation. It takes less than an hour per module to analyze and store the burn-in results. Summary of the findings will also be reported in the module traveler and in the module database, which has links to the recorded data plots.

The different tests performed during burn-in are the following:

- Temperature sensor test: performed at room temperature, before the SVX chip is powered.
- Data integrity check: tests the stability of downloading the SVX chip and verifies chip identification number (ID) and channel numbers of the SVX data for each chip.
- Long-term burn-in test: it consists of a number of runs with an idle interval between them in which the chips remain powered. In each run, the SVX chips are tested in “read all” and “read neighbor” modes. In “read all” mode, chip pedestals are read out to evaluate the noise in each SVX channel and the chip calibration is performed. In sparse readout mode (“read neighbor"), where only the channels

whose response exceeds the preset threshold and their immediate neighbors have to be read out, the frequency of false readouts is studied.

- These tests are performed with the module under bias
- The modules will be burned-in under normal room temperature of approximately 30 degrees Celsius without dry-gas purging. The typical bias current for the prototype modules does not exceed 100-200 nA. However, an option of flowing nitrogen gas is also available. This option can be used, e.g. for modules drawing currents in excess of 1 μA, in order to verify that the anomal current is not caused by humidity. For a detailed description of the tests performed during burn-in in Run IIa, see DØ Note 3841. We plan to run the same tests during Run IIb. A combined Hybrid and Module burn-in run lasts typically 100 hours; the duration might be reduced as production progresses if no failures are encountered and a larger throughput is required.

4.3 QA Test for Detector Modules

We plan to subject a small fraction (~10%) of detector modules to a thorough set of QA tests. The final set of tests will be developed based on already produced prototype modules. The current plan is to test modules in the following areas:

- Laser test: This test is meant to verify the response of the silicon sensor to a light signal. Detector modules will be placed on an x-y movable table enclosed in a dark box, biased and illuminated with a highly-collimated pulsed IR laser, providing a detailed test of each strip of the detector module in a functional setting. The same system was used during Run IIa. It is based on a 1-Saseq test stand, with the addition of the movable table, dark box, and Laser. The solid-state laser operates at a wavelength of 1064nm, a wavelength chosen because the high resistively silicon used in the detectors is partially transparent to it. The attenuation as a function of silicon thickness has been measured, resulting in an attenuation length of 206μm. This laser will thus test the whole depth of the 320μm thick detector and not just a surface layer. We plan to do a detailed scan of the modules to check for uneven response of the sensor to the laser.
- Temperature cycles: We consider that a detailed temperature cycle test, in which modules are read out and checked for mechanical integrity after being subject to temperatures of –10C, is desired. Such tests have been already performed on several hybrids without any adversary effects being noticed.
- Probe testing: We do have the ability to probe test silicon sensors after they were assembled into modules, or to do detailed checks of signals in the SVX chips by means of a logic analyzer and a probe tip. We can use this tools for QA tests if found appropriate once we gain experience during the R&D and pre-production phase.
- Pull Tests: we will test wire bonds on the hybrids and between hybrids and sensors on their pull strength during the R&D and pre-production phase, and might consider doing it in a small fraction of modules during production if needed.

5 SUMMARY

Drawing on the experience from Run IIa a comprehensive QC/QA program has been established to ensure that the rapid production required for Run IIb can proceed with minimal cost and schedule risk. Electrical testing steps are in place following potentially risky mechanical assembly, typically within a few days. This ensures that any systematic problems can be quickly identified and remedied before a significant number of parts are affected. Written procedures, training and readiness reviews are integrated into our plan to ensure production quality from the outset.

References:

1. http://d0server1.fnal.gov/projects/run2b/silicon/www/smt2b/Testing/SaseqTS-Description.pdf

2. D0 Layer 0 conceptual design report. D0 note 4415

3.http://d0server1.fnal.gov/projects/run2b/Silicon/Readout/Hybrids/L0hybrid/hybrid_QC_AB062804.doc