Appendix 1: Acceptance Tests to be carried out by the ATLAS Institutes

1 Tests on Detectors as delivered

The role of the ATLAS Institutes during production testing is mainly that of a visual inspection and of an electrical IV measurement on every detector as a check on the basic quality. However, on a subset of detectors (expected to be 10-20% initially, but reducing to ~5% with experience during production), a thorough evaluation of detector (and test-structure where possible) characteristics will be performed as a check on processing consistency and as a verification of the Contractor's tests.

1.1 Tests on every detector

1.1.1 Visual inspection

Aim: To ensure the detector is free from physical defects and scratches.

Procedure: Place the detector on a probe-station chuck and scan it visually using a microscope.

Acceptance: The detector is free from significant scratches and blemishes. The cut edge is straight, clean and free from chipping. No chips or cracks should extend inwards by more than 50µm.

1.1.2 IV Curve

Aim: To perform a basic check of detector quality, to cross-check with Contractor data and to ensure there has been no transit damage.

Procedure: This test requires a voltage source/picoammeter (SMU). The detector backplane is placed on the chuck of a probe-station and the IV characteristic between the bias rail and the backplane measured using the SMU. The detector bias may be applied via a front edge contact instead of via the detector backplane if appropriate. The current is measured in 10V steps from 0V up to 350V, with a 10 second delay between steps. The temperature of the probe-station environment should be recorded.

Acceptance: The detector displays a characteristic at 20°C which is below 6µA at 150V and below 20µA at 350V, and which agrees with the Contractor's data to within the agreed tolerances.

1.2 Tests on a detector subset

These tests are a verification of the measurements performed by the Contractor. If any of these tests fail, this is an indication of either a variation in processing and/or a possible failure in the testing procedures of the Contractor. Further samples from the batch should then be tested and contact made immediately with the Contractor.

1.2.1 Detector depletion voltage

Aim: To determine the depletion voltage and verify the Contractor's data.

Procedure: This measurement requires a CV meter equipped (if necessary) with an external bias adaptor and a voltage source. Place the detector backplane on the chuck of a probe-station and contact the bias rail with a probe needle. Connect the probe needle to the AC output of the CV meter bias adaptor, and the backplane to the voltage output of the CV meter bias adaptor. Alternatively the capacitance can be measured between the bias rail and the front edge contact if appropriate. Record the capacitance in 10V steps up to 350V, with a 10 second delay between steps. Use 1 kHz with CR in SERIES. Plot the data as $1/C^2$ ($1/nF^2$) vs bias (volts), and extract the depletion voltage.

Acceptance: Depletion < 150V

1.2.2 Strip integrity

Aim: Check each strip for punch-throughs to the oxide, for shorts between strip metals, and for discontinuities in the strip metals as a verification of Contractor supplied data and to check that the strip defects are within specifications.

Procedure: This test requires a volt source / picoammeter (SMU) to check for oxide punch-throughs, a CV meter to measure capacitance, and a switching matrix. The detector is placed on the chuck of an automatic probe-station, and strip metal pads corresponding to Row C for Barrel detectors or Row B for Forward detectors are probed under computer control with the light on. Punch-throughs across the strip oxide are determined by a measurement of current between the strip metal and backplane with -100V on the needle and the detector backplane at ground potential. A series resistor of ~2-5Mohm should be used to limit the current in case of pinholes. The following technique for each strip measurement has been demonstrated to work well without any damage to the detector, and is therefore recommended, though alternative techniques are acceptable:

1. Switch the probe-needle to the high output of the SMU sourcing 0V, and the backplane to grounded low output of the SMU.
2. Step to strip n and raise the chuck
3. Increase the SMU source to -10V, wait 1 second and measure the current to determine electrical continuity across the oxide. If there is electrical continuity (ie a pinhole exists at low volts) skip steps 4 and 5 and go to step 6.
4. If there is no electrical continuity, increase the SMU source to -100V (no ramp), wait 1 second and recheck the electrical continuity.
5. Decrease the SMU source to 0V (no ramp).
6. Switch the probe-needle to ground (ie short the needle to the detector backplane) and wait for 500ms
7. Switch the probe-needle to the AC output of the CV meter, and the backplane to the voltage source of the CV meter (with the CV meter sourcing 0V).
8. Wait 1 second and measure the capacitance (at 1kHz, with CR modelled in SERIES)
9. Lower the chuck

10.Repeat the measurement cycle from point 1 above for strip n+1.

The test (as demonstrated on a SUMMIT 10K probe station) takes about 1 hour 10 minutes.

Detector Acceptance: < 2 % bad strips, where a bad strip has electrical continuity between the strip metal and backplane, strip metal short to neighbour or evidence for metal discontinuity.

and agreement with the Contractor on the list of identified bad strip numbers within the agreed tolerance.

Batch Acceptance: The batch is accepted if the mean number of good strips is ≥99% and no detector falls below 98% good strips.

1.2.3 Leakage Current Stability

Aim: To check that any variation in leakage current over a 24 hour period is within specifications.

Procedure: This test requires a voltage source / picoammeter (SMU), a meter for temperature monitoring, an environment chamber, and, if available, a switching matrix. Detector is assembled into a support frame and the backplane and bias rail are bonded to soldable contacts. The backplane and bias rail of the detector are connected to the high and grounded-low outputs of the SMU respectively. The assembly is installed in an environment chamber containing dry air (nitrogen) maintained at 20°C. The bias is ramped to 150V, and after 60 seconds settling time the current is monitored every 15 minutes over a 24 hour period. Several detectors may be measured in parallel by use of a switching matrix.

Acceptance: Maximum increase in leakage current during 24hours is less than 2µA.

1.2.4 Full Strip Test

Aim: To measure the polysilicon bias resistance and coupling capacitance for every strip, and to check for pinholes, strip metal shorts and opens, implant breaks, and electrical contact between the polysilicon resistor and strip implant.

Procedure: This test requires all 768 strips to be probed while the detector is partially depleted via contacts to the bias rail and backplane. The test requires a voltage source to deplete the detector, a voltmeter/picoammeter (SMU) to check for pinholes, a CV meter for a CR calculation, and a switching matrix. Either mount the detector into a frame and bond the bias rail and backplane to soldable contacts or, if a probe needle manipulator can be fixed to the moving chuck, place the detector directly on to the chuck and contact the detector bias rail with the chuck-mounted probe-needle. If the option of mounting the detector into a frame is used, attach the frame to the probe-station chuck using a jig which permits adjustment of the planarity of the detector so that it is flat with respect to the platen of the probe-station. Switch off the light and apply +20V to the detector backplane with the bias rail at ground potential in order partially to deplete the detector. Under computer control, probe all 768 strip pads along row C for Barrel detectors or row B for Forward detectors according to the following instructions:

1. Switch the high output of the SMU (sourcing 0V) to the probe-needle via a 2-5Mohm series resistor, and switch the low output of the SMU to the detector bias rail.
2. Step to strip n and raise the chuck
3. Increase the SMU source to -10V, wait 1 second and measure the current to determine electrical continuity across the oxide. If there is electrical continuity (ie a pinhole exists at low volts) skip steps 4 and 5 and go to step 6.
4. If there is no electrical continuity, increase the SMU source to -100V (no ramp), wait 1 second and recheck the electrical continuity
5. Decrease the SMU source to 0V (no ramp)
6. Switch the probe-needle to ground (ie short the needle to the detector backplane) and wait for 500ms
7. Switch the probe-needle to the AC source output of the CV meter, and the bias rail to the voltage source output of the CV meter, with the CV meter sourcing 0V.
8. Wait 1 second and measure C and R (at 100Hz, with CR modelled in SERIES)
9. Lower the chuck
10. Repeat the measurement cycle from point 1 above for strip n+1.

The test (as demonstrated on a SUMMIT 10K probe-station) takes about 1 hour 10 minutes. The measured values of R and C yield the polysilicon resistor value and coupling capacitance respectively. Deviations imply a strip defect as listed above. Note the test may be performed at 1kHz if measurements at 100Hz are not possible or are unstable; at 1kHz the coupling capacitance is underestimated by 10-20%.

Acceptance: The number of strips with a significant deviation from the mean of the capacitance and resistance distributions must be <2%.

1.3 Diagnostic Tests

This article lists the recommended procedures for a more detailed evaluation of detector electrical parameters should acceptance tests indicate that some variation in processing has occurred. After any diagnostic tests on the detector, the IV measurement listed in article 1.1.2 should be repeated.

1.3.1 Interstrip Capacitance

Aim: To ensure the interstrip capacitance is within specifications.

Procedure: This test requires a CV meter and a voltage source. Place the detector on the chuck of a probe-station, and contact the bias rail by probe-needle. The backplane and the bias rail should be connected to the high and grounded-low sides (respectively) of the voltage source. Contact three adjacent metal strips (pad row C for Barrel detectors or row B for Forward detectors with probe needles. Contact the central strip to the AC output of the CV meter, and the neighbours to the voltage output (with the CV meter soucing 0V). Measure the capacitance between the central strip and its neighbours on both sides as a function of detector bias up to 150V. Use 100 kHz test frequency with CR in parallel.

Acceptance: Interstrip capacitance < 1.1 pF/cm at 150V bias.

1.3.2 Polysilicon Bias Resistance and Interstrip Resistance

Aim: Determine the bias resistor value is within specifications and that the interstrip isolation is sufficient when under bias.

Procedure: This test requires a voltage source and a volt source/picoammeter (SMU). This measurement yields both the polysilicon bias resistance and the interstrip resistance. Place the detector backplane on the chuck of a probe-station and contact the bias rail and a strip implant by probe-needles. The backplane and bias rail should be connected to the high and grounded-low outputs (respectively) of the voltage source. The strip implant and bias rail should be connected to the high and low outputs (respectively) of the SMU. Perform an IV (using the SMU) up to 1V to determine the resistance between the strip implant and bias rail as a function of bias voltage (increase detector bias from 0 V to 5 V in steps of 0.2 V).

Acceptance: Interstrip resistance is sufficient if the measured resistance vs detector bias plateaus. The plateau level resistance is equivalent to the polysilicon bias resistance, and must be within 1.25 ± 0.75 MΩ.

1.3.4 Metal Series Resistance

Aim: To determine that the strip metal resistance is within specifications (deposited metal is sufficiently thick) and to monitor processing consistency.

Procedure: This test requires an ohmmeter or a voltage source / picoammeter (SMU). Apply an ohmmeter (or perform an IV using the SMU) between the two ends of the appropriate metal line test-structure (if available) or to either end of one of the detector metal strips (if no test-structure available).

Acceptance: Series resistance < 15Ω/cm

1.3.5 Coupling Capacitance

Aim: To determine the coupling capacitance between the strip metal and strip implant, to check that the value is within specification and to monitor processing consistency.

Procedure: This test requires a CV meter. Place the detector backplane on the chuck of a probe-station and contact the metal and implant of a strip with probe needles. Connect the strip metal and implant to the AC and voltage outputs (respectively) of the CV meter, with the CV meter sourcing 0V. Measure the capacitance between the metal and implant at 1 kHz with CR in PARALLEL.

Acceptance: Coupling capacitance ≥ 20 pF/cm

1.3.6 Implant sheet resistance

Aim: Measurement of sheet resistance of p implant, to check that the value is within specifications and to monitor processing consistency.

Procedure: This test requires an ohmmeter or a voltage source / picoammeter (SMU), and requires the use of the appropriate test-structure if available. Contact the ohmmeter (or perform an IV using the SMU) between the two contacts of the sheet resistor test-structure.

Acceptance: Sheet resistance < 200 KΩ/cm

1.3.7 Flat band voltage

Aim: To determine flat band voltage as a monitor of processing consistency.

Procedure: This test requires a voltage source, and a CV meter equipped (if necessary) with an external bias adaptor. The measurement requires a MOS test-structure if available. Place the MOS on a probe-station chuck and contact the MOS with a probe needle. Connect the MOS metal and the backplane to the AC and voltage outputs (respectively) of the CV meter. Measure capacitance across the MOS (at 1kHz with CR in SERIES) as a function of bias up to 50V.

Acceptance: There is no defined acceptance criterion. Flat band voltage is used as a monitor of processing consistency.

2 Post-Irradiation Tests on detectors

A small number (probably around 1%) of full-sized detectors will be selected for irradiation during production, and a thorough evaluation of these detectors will be performed for detailed comparisons with the requirements of the Tender documents and the data from the Qualified Prototypes. It is anticipated that larger numbers of miniature detectors (identical to the full-size detector (of barrel geometry) but only 1cm^2 in size with 98 strips of 8mm length) will be used for irradiation tests, as their small size means that they can be irradiated more quickly and easily. It is anticipated that the measurement of the post-irradiation IV characteristics of miniature detectors will provide a minimum check of processing consistency.

2.1 Tests before detector irradiation

On delivery the full set of detector measurements described in article 1 of Appendix 1 should be performed to ensure the detector is fully characterised. The detectors are then glued with araldite 2011 to ceramic support cards and bonded to pitch adaptors for compatibility with readout by both binary and analogue readout electronics. During irradiation the strip metals are shorted together (via bonds on the pitch adaptor to a common rail) to simulate the condition of being bonded to readout electronics. The detector bias rail and backplane must be connected to ~3cm long leads (via bonds to the pitch adaptor and/or flexible PCB) terminating in 2-pin SIL connectors for biasing. The IV characteristics shall be remeasured after gluing to ensure no deterioration has occurred during assembly.

2.2 Post-Irradiation Tests

Unless otherwise specified, all post-irradiation detector tests are performed cold (-10°C) in a freezer containing dry air, and with the detector ceramics screwed to an aluminium support frame protected by an aluminium cover lid. To ensure good thermal contact, the aluminium support frame should itself be in direct contact with a large thermal mass inside the freezer. Annealing times (when the detector is brought to room temperature for measurements, bonding/soldering work etc) should be recorded in units of days at 25°C equivalent temperature.

2.2.1 Annealing

After irradiation the detectors should undergo a controlled beneficial anneal for 7 days at 25°C, taking them to the minimum region of the depletion voltage.

2.2.2 IV Curve

Aim: To measure the IV characteristic after irradiation.

Procedure: This test requires a voltage source/picoammeter (SMU) to measure the IV characteristic between the bias rail and the backplane. The current is measured at -18°C at every 10V step up to 500V, with a 10 second delay between steps. The temperature of the detector should be recorded (either via a PT100 on the detector ceramic, or a PT100 in contact with the large thermal mass inside the freezer). On a sub-sample of detectors, the IV should be remeasured at -10°C to verify that the current scales in the expected way with temperature.

Acceptance: The detector displays a characteristic at -18°C which is below 250 µA at bias voltages up to 450V.

2.2.3 Strip Integrity

Aim: To check for additional oxide punch-throughs caused by the irradiation.

Procedure: This test requires a volt source/picoammeter (SMU) to check for oxide punch-throughs, and a CV meter to measure capacitance anomalies due to strip metal shorts/opens and pitch adaptor scratches/shorts. The detector is warmed to room temperature and the lid of the aluminium frame is removed. Any bonds still connecting strip metals to the common ground rail of the pitch adaptor must be removed. The frame is attached to a jig on the chuck of an automatic probe-station, and the planarity adjusted such that the pitch adaptor is flat relative to the probe-station platen. All metal pads of the pitch adaptor are then probed (in 4 groups of 128) under computer control with the light on. +10V is supplied continuously by the SMU to the backplane via the voltage output of the CV meter (or the external bias adaptor of the CV meter if applicable), with the needle connected to the AC output of the CV meter. A series resistor may be necessary to limit current if the CV meter external bias adaptor (which usually contains a large series resistance) is not used. The following technique for each strip measurement has been demonstrated to work well without any damage to the detector, and is therefore recommended, though alternative techniques are acceptable:

1. Before the first pitch adaptor pad is probed, source +10V from the SMU and wait several seconds for the SMU current to drop to <1nA (due to the capacitor charging in the CV meter external bias adaptor)
2. Raise the chuck to contact the pad with the probe-needle.
3. Measure the current drawn from the SMU. Currents 1nA indicate an oxide punch-through
4. Measure the capacitance (1kHz, CR in SERIES, 100mV amplitude).
5. In the case of an oxide punch-through, drop the chuck and wait several seconds for the SMU current to resettle to <1nA. If there is not oxide punch-through, no delay is necessary.
6. Move to the next pad, and repeat from Step 2 above.

The test (as demonstrated on a SUMMIT 10K probe-station) takes about 25 minutes.

Acceptance: The number of strip defects (due to oxide punch-throughs and strip metal defects) is < 2%.

2.2.4 Leakage Current Stability

Aim: To check that any variation in leakage current over a 24 hour period is within specifications.

Procedure: This test requires a voltage source / picoammeter (SMU), a meter for temperature monitoring, an environment chamber, and, if available, a switching matrix. The backplane and bias rail of the detector are connected to the high and grounded-low outputs of the SMU respectively. The assembly is installed in freezer containing dry air (nitrogen) maintained at -10°C. The bias is ramped to 350V, and after 60 seconds settling time the current is monitored every 15 minutes over a 24 hour period. Several detectors may be measured in parallel by use of a switching matrix.

Acceptance: Maximum variation in leakage current during 24hours is less than 3%, after correcting for any temperature fluctuations.

2.2.5 Interstrip Capacitance

Aim: To determine that the interstrip capacitance is within specifications.

Procedure: This test requires a CV meter and a voltage source, and requires the detector aluminium support frame to be attached to a jig to allow for bonding from the strip pads on the pitch adaptor to solderable contacts (eg a piece of PCB with appropriate gold tracking). Remove the bonds (if not already removed) connecting the detector strips to the common ground rail on the pitch adaptor. From one of the rows of 128 pads on the pitch adaptor that corresponds to 6cm strips, bond one strip pad out to a solderable contact on the PCB, and bond the two neighbouring strip pad on both sides to the common ground rail of the pitch adaptor. Bond out from the common ground rail to a second solderable contact on the PCB. The central strip should then be connected (via a cable soldered to the PCB) to the AC output of the CV meter, and the two neighbouring strips to the voltage output of the CV meter (sourcing 0V). The backplane and bias rail of the detector should be connected to the high and grounded-low sides (respectively) of the voltage supply. Measure the capacitance between the central strip and its neighbour on both sides as a function of detector bias up to 500V, using 20V steps. Use 100kHz test frequency with CR modelled in parallel. Note: parasitic capacitance arising from the PCB and its cabling to the CV meter needs to be subtracted from the measured capacitance values. The best way to estimate the parasitic capacitance is to remove the bond between the pitch adaptor and PCB that connects the central strip, and remeasure capacitance.

Acceptance: Interstrip capacitance < 1.5 pF/cm at 350V bias.

2.2.6 Polysilicon Bias Resistance and Interstrip Resistance

Aim: Determine the bias resistor value is within specifications and that the interstrip isolation is sufficient when under bias.

Procedure: This test requires a voltage source and a volt source / picoammeter (SMU). This measurement yields both the polysilicon bias resistance and the interstrip resistance, and must be performed cold (-10°C). The backplane and bias rail should be connected to the high and grounded-low outputs (respectively) of the voltage source. The DC contact to a strip implant and bias rail should be connected to the high and low outputs (respectively) of the SMU (it is necessary to bond from the strip DC contact to a track on the pitch adaptor. Some bonds from the strip metals to the pitch adaptor will need to be removed to provide space for this). Perform an IV (using the SMU) from -5V to +5V to determine the resistance between the strip implant and bias rail as a function of bias voltage (increase detector bias from 0 V to ~300V or until the measured resistance plateaus).

Acceptance: Interstrip resistance is sufficient if the measured resistance vs detector bias plateaus. The plateau level resistance is equivalent to the polysilicon bias resistance, and should be within 1.25 ± 0.75 MΩ.

2.2.7 Charge Collection Efficiency

Aim: To determine the onset of the plateau in charge collection efficiency vs detector bias up to 500V.

Procedure: Bond one group of 6cm 128 channels to an analogue readout chip with an effective peaking time of 25ns and measure the signal collected vs bias triggered using a Ru^{106} beta-source.

Acceptance: The onset of the plateau matches the value observed for the Qualified Prototypes and the operating voltage required for >90% of maximum achievable charge collection efficiency is < 350V.

2.2.8 Strip Quality vs Bias

Aim: To determine the number of strips with excess noise due to microdischarge.

Procedure: Bond all channels of the pitch adaptor to either binary or analogue readout electronics with an effective peaking time of 25ns, and measure the noise per channel vs detector bias at 200V, 300V, 400V and 500V bias.

Acceptance: There is < 5% increase in the measured noise of any channel due to microdischarge on raising the detector bias from 300V to 400V.