PIPER Series Array Chip Screening Plan

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Overview

The new series array chips for the 2-stage SQUID readout system have the same pad configuration and geometry as the series array chips for the 3-stage SQUID readout system. As such, PIPER will re-use the designs and hardware originally intended for the 3-stage readout.

Each series array chip is permanently mounted onto a toothbrush board. Each toothbrush board has 6 sockets at one end (3 pairs: IN, FB, BIAS). Four toothbrush boards are clamped together into a single module by a copper capture comb. Shielding is provided by a 10:1 aspect ratio welded niobium box with a closed end that is slid over the four boards. The sockets on the four boards then form a 4x6 female receptacle which can be reversibly mated to a bed of pins, e.g. on the series array backplane or a dip probe.

The assembled modules are flight modules.

A module of this design is in use in the SHINY SQUID readout and has not exhibited any issues.

The series array chips will be screened after they have been mounted onto their toothbrush boards and assembled into modules using a dip probe inserted into a LHe storage dewar. A single module (i.e. 4 series array chips) may be tested in each dip test.

PIPER requires enough series arrays to run 4 MCEs. Each MCE requires 8 modules of 4 toothbrush boards, for a total of 32 series array chips per MCE. Thus, PIPER requires 128 working series array chips. Assuming a 100% yield, this corresponds to 32 dip tests.

Toothbrush Boards

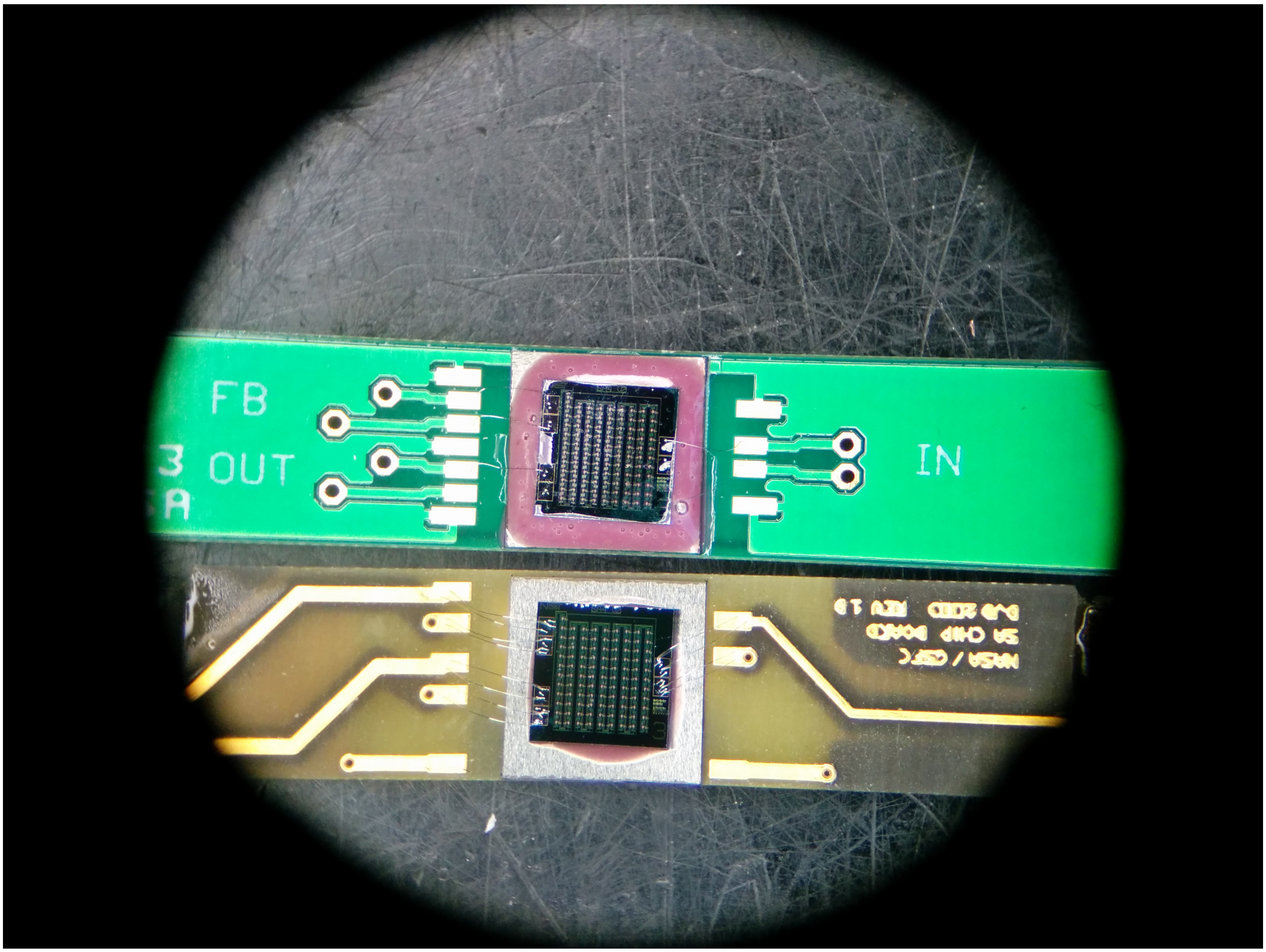
The toothbrush boards are designed to position the series array chips far inside the 10:1 aspect ratio closed-end welded niobium shield.

The series array chip is mounted near the end of the board with a square of niobium foil underneath.

Toothbrush board assembly:

1. Bond using Hysol EA 9309.3 epoxy a 0.25" x 0.25" x 0.005" square of niobium foil to the bond pad.

   Let cure for 1 hour at 50 deg C.
2. The SSA chips come coated with photoresist. Clean the photoresist by alternating between acetone and alcohol, ending with alcohol.
3. Bond using Hysol EA 9309.3 epoxy the SSA chip onto the niobium foil. Make sure the bond pads on the board correctly align with the bond pads on the SSA chip.
4. With aluminum wedge bonds, wirebond the SSA chip to the toothbrush board. This should require 6 wirebonds: one pair for each of IN, FB, and BIAS. See below for a completed example.
5. *[optional]* With gold wedge bonds, make thermal wirebonds from the toothbrush board to the SSA chip.



Toothbrush Modules

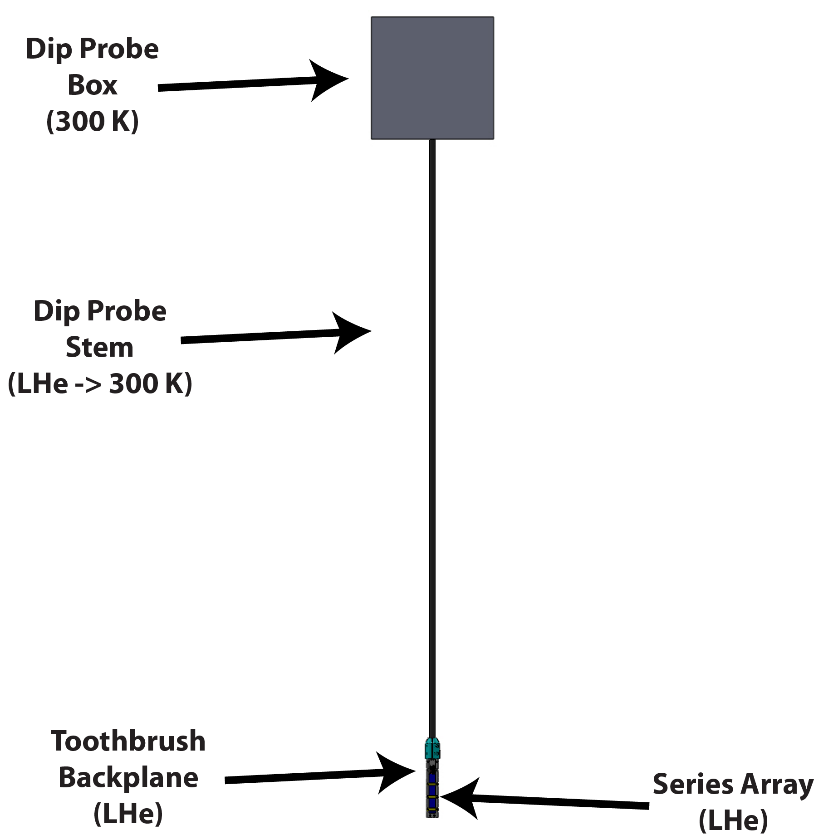
The toothbrush boards are assembled into modules. Each module holds 4 toothbrush boards. The modules are intended to provide a means of magnetically shielding the series arrays and to provide a convenient connectorization of the series arrays.

Toothbrush module assembly:

1. ...
2. The procedure for assembling the toothbrush modules has been demonstrated previously.
3. It is not yet reproduced here.
4. ...

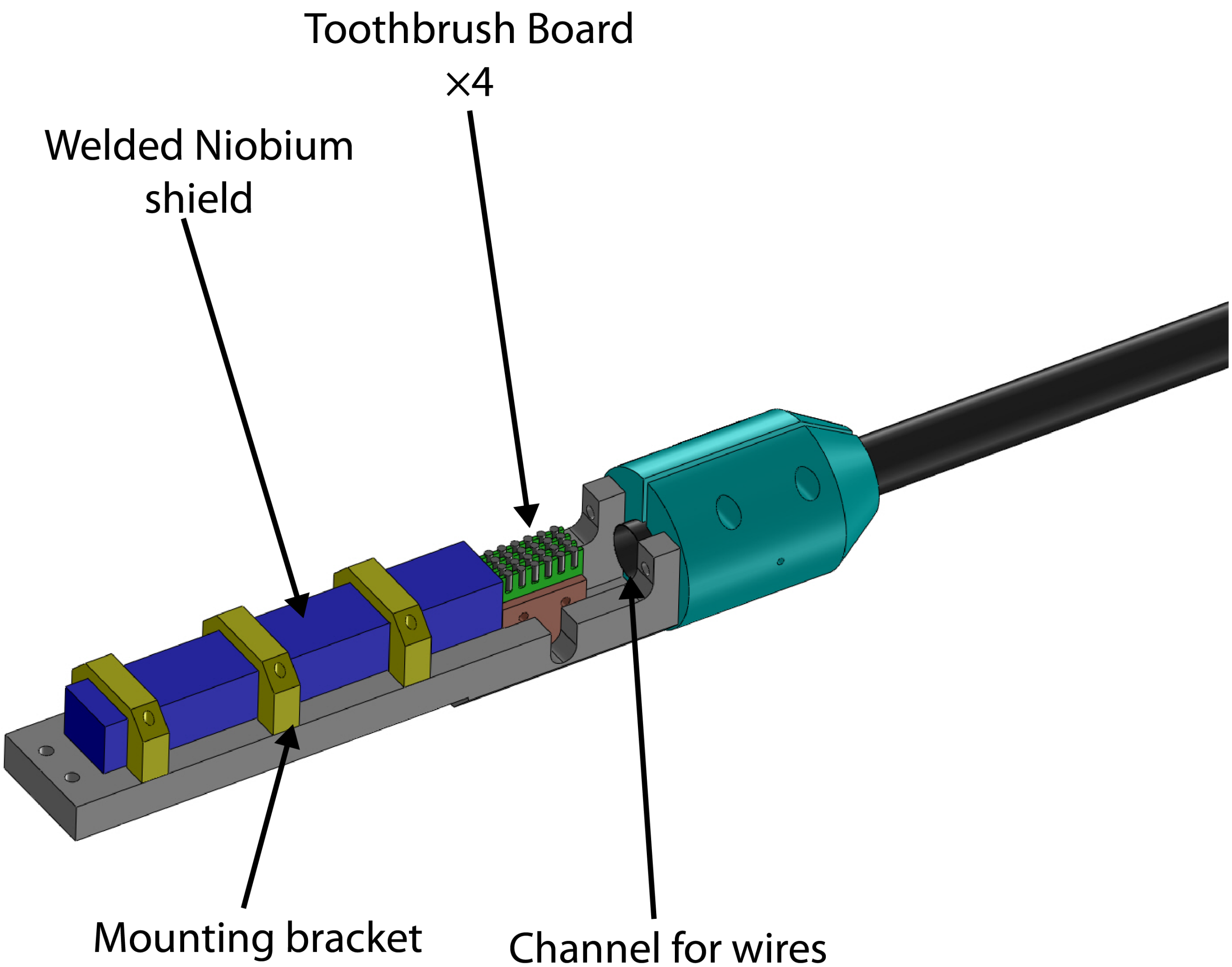
Dip Probe

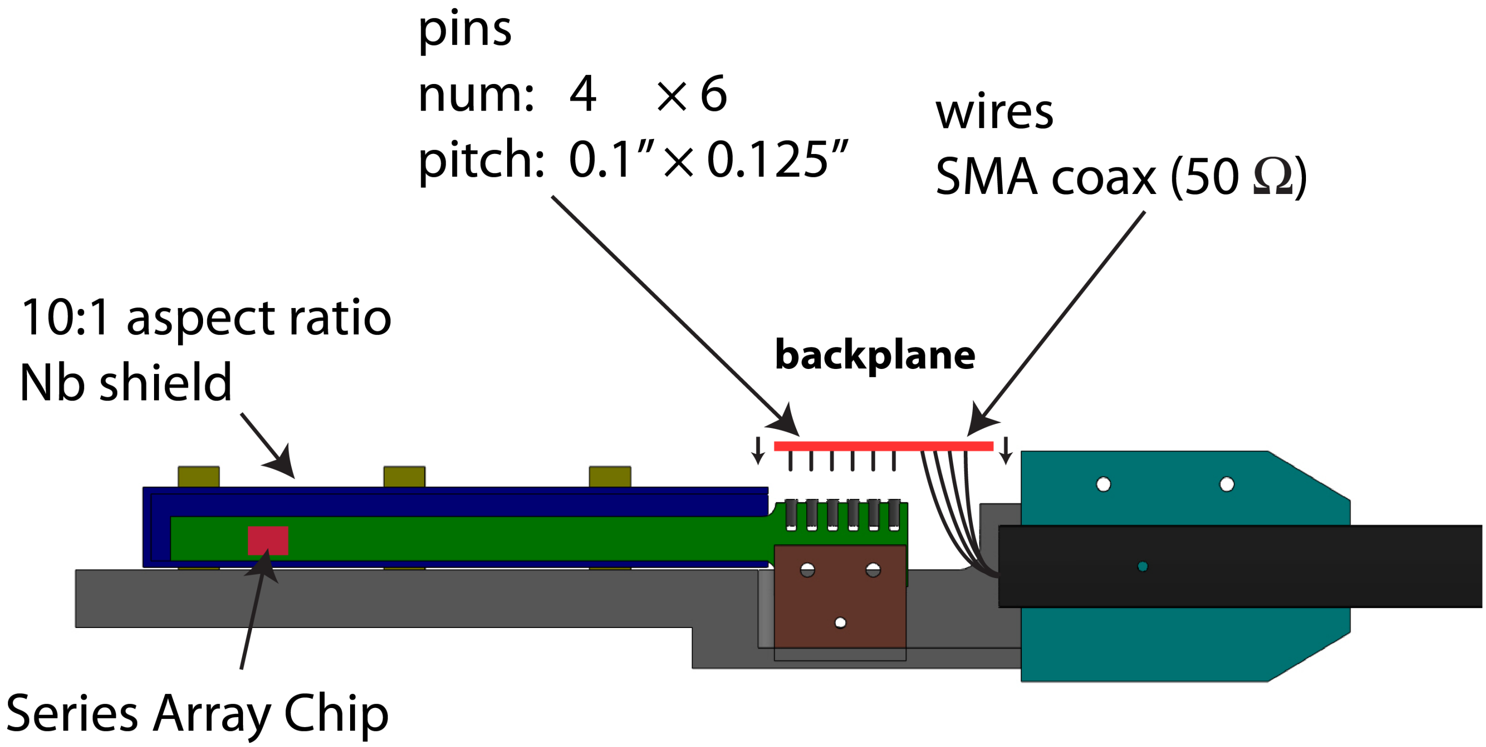
The dip probe provides a mounting bracket for immersing a toothbrush module in LHe in a 100 L storage dewar and provides electrical connections to the SSA.



Mechanical

The dip probe consists of a warm breakout box, a long stem, and a cold mounting bracket for the toothbrush module. The warm breakout box has BNC connectors for accessing all parts of all 4 channels of the SSA chips in the modules, and also houses the amplifier board that reads out the SSAs. The stem houses the SMA cables that extend from the warm amplifier board to the toothbrush backplane. The toothbrush backplane has a grid of 4 x 6 pins that connect to the sockets of the toothbrush module. The toothbrush module and niobium shield is secured by an aluminum mounting bracket.



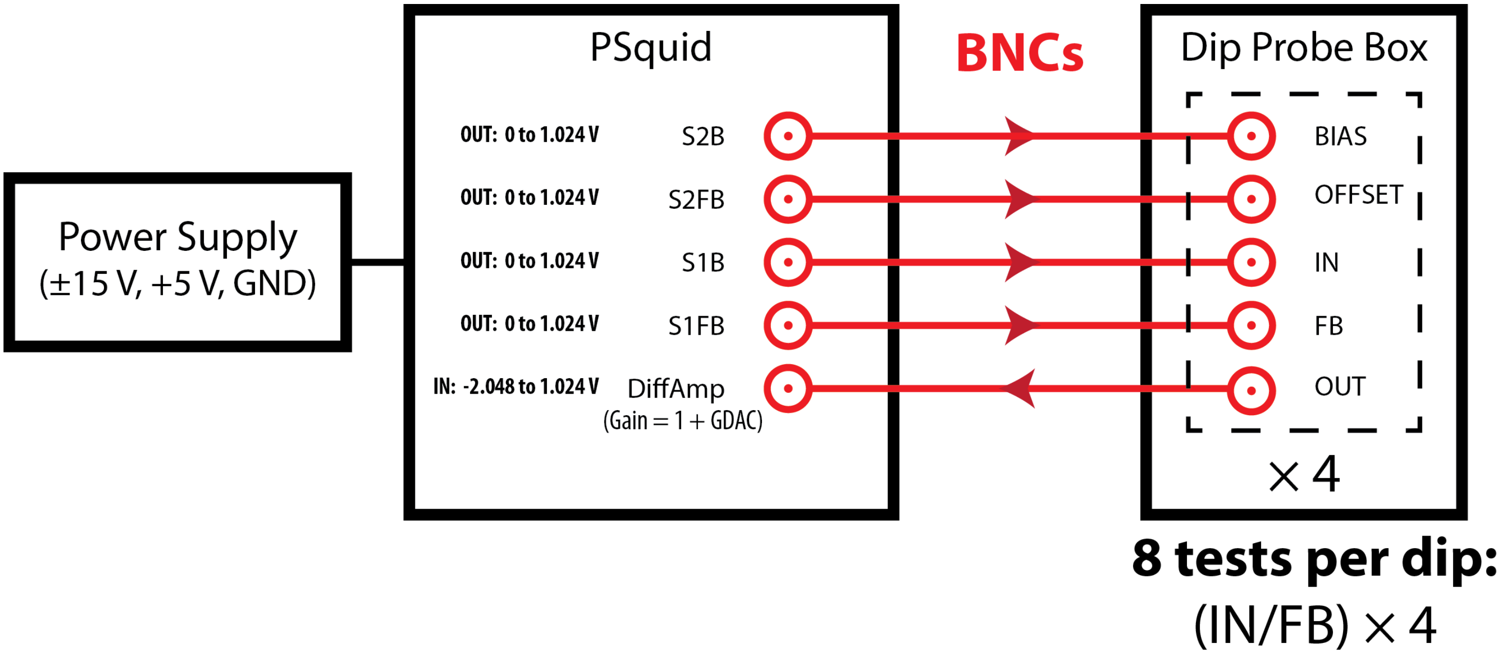


Electrical

The PSquid SQUID controller board will be used to drive the series array. While the PSquid board is capable of driving the series arrays with no additional electronics, we will not be utilizing this capability. The dip probe was designed for a previous generation of SSA screening tests 3 years ago and was designed with biasing and readout circuitry. We will use the dip probe's circuitry and use the PSquid board as a fast ADC/DAC card, since this scheme requires no modifications to the hardware.

The PSquid board was used for the SPTC measurements in SHINY in March 2014. The dip probe was used for screening 32 old style series arrays in the spring of 2012. There are no concerns about untested hardware.

The PSquid and dip probe are connected as shown:

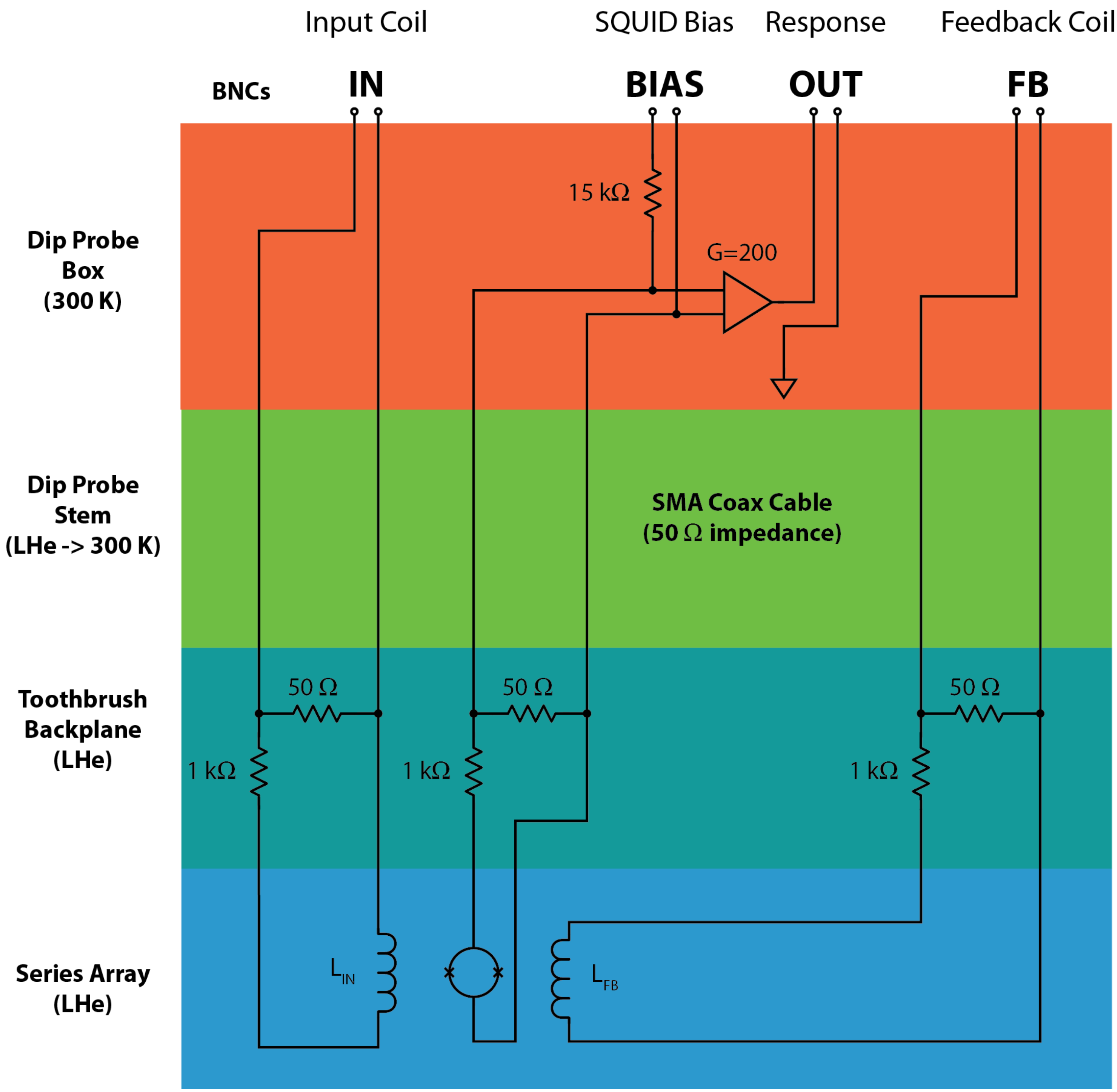


PSquid requires +-15 V and +5V. The screening process is not expected to require especially low noise, so a switching power supply will be used. BNCs connect the PSquid board and dip probe box. All PSquid connections except DiffAmp are DACs. The DiffAmp connection is the input to an ADC on the PSquid board. Note that the PSquid signal names do not match the dip probe signal names. This is because the PSquid bias circuitry is being bypassed and we are just using the PSquid channels as DACs and all of the S1 and S2 outputs on PSquid are identical. They all have an output range of 0 to 1.024 V and can source ~20 mA. The signal names on the dip probe match their functionality, since we are using the dip probe bias circuitry.

The DiffAmp PSquid input passes through an instrumentation amplifier and adjustable gain amplifier. The amplifier chain has a minimum gain of 1 and a maximum gain of over 10^5. It is read out by a +- 2.048 V 16-bit ADC.

Only a single channel of the series array module can be read out at a time. The BNCs will be moved to read out the other channels.

The dip probe is shown schematically:

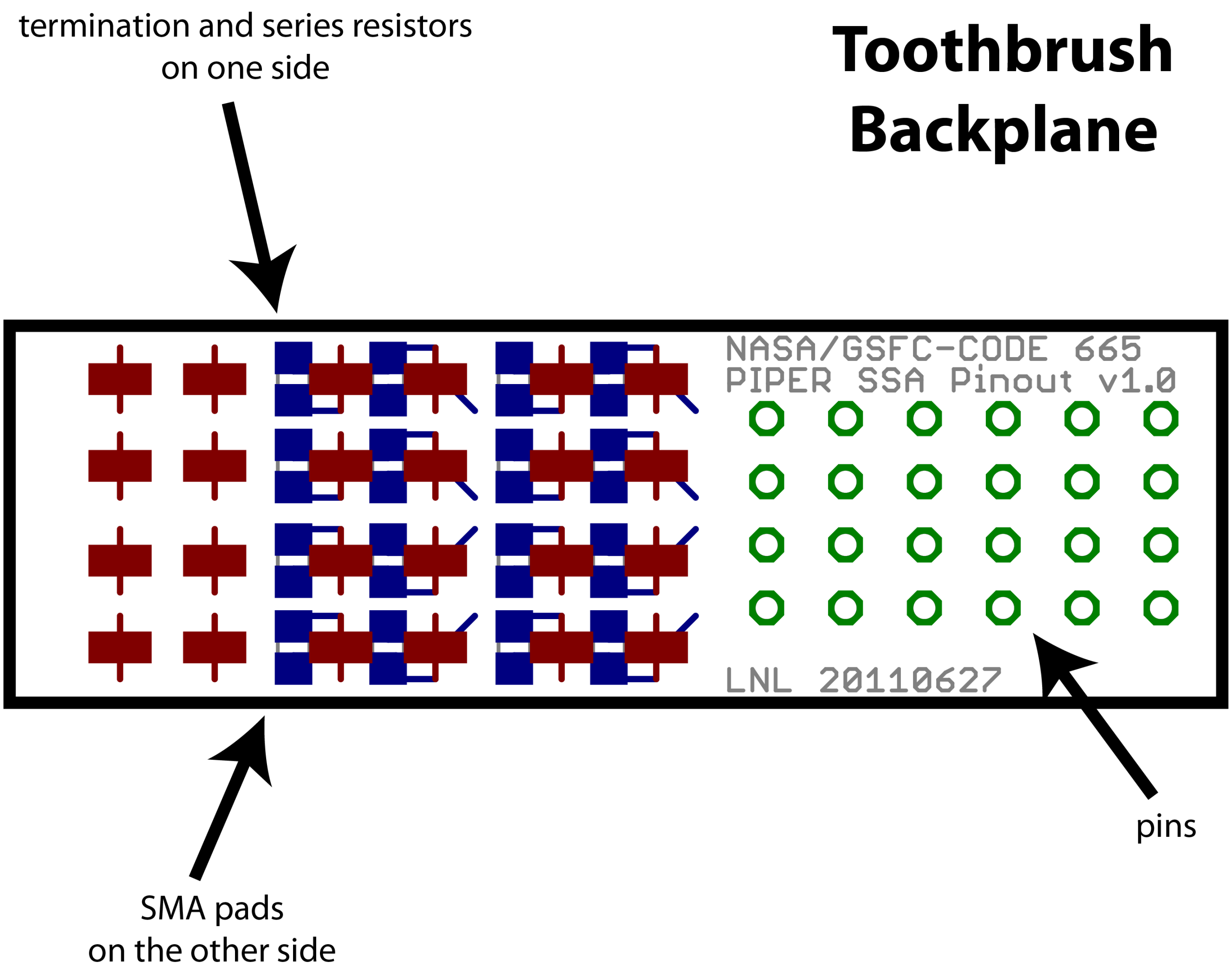


The IN (input) and FB (feedback) signals are sent straight down to the toothbrush backplane via 50 Ohm SMA coax, where they are terminated by a 50 Ohm resistor and converted to a current bias by a 1 kOhm resistor.

The BIAS (S3 bias) signal follows a standard SQUID biasing path. It is transported to the toothbrush backplane by 50 Ohm SMA coax and terminated by a 50 Ohm resistor. The 1 kOhm series resistor converts the signal back to a current bias.

The amplifier is a copy of the amplifier used in the MCEs and has a gain of 200.

Toothbrush Backplane



The toothbrush backplane is a small board that converts from SMA to the bed of pins necessary to connect to the toothbrush module and provides termination and series resistors. The SMA cables are soldered sideways onto large pads on one side of the board. On the other side of the board are the resistors and pins.

The toothbrush backplane connects to the toothbrush module and completes the connection to the series arrays.

Software and Test Strategy

The PSquid software has already been developed for the single pixel tests. A test controller script will be written to automate the testing. The testing may be automated with little difficulty to the point that technicians and interns are capable of operating the apparatus without supervision.

PSquid has built-in sweep functionality that allows it to sweep through DAC settings in a stairstep pattern while measuring the response. A typical dwell period at each step is ~10 ms (~100 Hz). This period is chosen to have a node near 60 Hz and provide a long settling period after the stairstep. However, the dwell period can be as fast as 1 kHz. For the 100 Hz rate, a 100 x 100 grid of FB and IN values can be completed in 100 seconds. For four channels, we require less than 10 minutes of testing.

The PSquid board is capable of sampling at up to 10 kHz. If necessary, the step response can be measured with up to a 5 kHz bandwidth.

An automated data reduction script will be written to reduce and tabulate the data.

Chip Failure

Chips that fail the screening must be replaced. The chips are not intended to be removed from the toothbrush boards, nor is it cost effective to attempt to do so. Rather, if a replacement chip is required, a new toothbrush board will be made.

The capture combs may be opened and the toothbrush board with the failed chip may be removed and replaced. The module is then reassembled as normal and the entire module is retested.

Hardware Procurement

No hardware needs to be procured before testing may commence.

- Dip Probe: 2 available
- PSquid: 1 available
- Toothbrush boards: ~150 available
- Capture combs: ~40 available
- Niobium foil squares: ~50 available (need ~75 more)

Schedule

The time required to perform the tests is then dominated by the time it takes to prepare and dunk the samples.

The time required to assemble toothbrush board and modules must be performed regardless and is not included in this accounting. The time required to write the automation and reduction scripts are also not included, since they must also be done regardless of strategy.

- Mounting toothbrush module into dip probe: 10 minutes

- Dipping probe into storage dewar and connecting electronics: 15 minutes
- Running tests: 10 minutes
- Extracting and warming probe: 30 minutes (with heat gun, longer without)
- TOTAL: ~1 hr

PIPER requires 32 modules to be tested for a total of ~30 hours of work.

2 dip probes are available, but only 1 PSquid card is available. By alternating the dip probes, the amount of attended work could be cut down to about 20 hours, since the warming of the probes may be left unattended.

The testing phase could be reasonably completed with 1-2 weeks of testing.