Novel Pogo-Pin Socket Design for Automated Low Signal Linearity Testing of CT Detector Sensor

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Abstract
Due to the arrayed nature of the Computed Tomography (CT) Detector, high density area array interconnect solutions are critical to the functionality of the CT detector module. Specifically, the detector module sensor element, hereby known as the Multi-chip module (MCM), has a 544 position BGA area array pattern that requires precise test stimulation.

A novel pogo-pin block array and corresponding motorized test socket has been designed to stimulate the MCM and acquire full functional test data. The pogo-pin block design has specific features which capture and guide the pogo-pins while still allowing for easy pin replacement at the test vendor. In addition, the socket design includes many unique design elements, including built-in protection for the pogo-block from user access, thermal control considerations, and stop features to prevent over clamping. Additional mechanical design features to blind-engage a flexible circuit with the MCM will be discussed. The entire socket and pogo-block system is replicated to create a multi-socket tester that is currently deployed at the OEM vendor.

This test system enables full characterization of the MCM including gain connectivity testing and full linearity testing of the device. Various additional aspects of the test system will be discussed, including software control of the socket and data collection of the entire signal chain. This type of test socket architecture can be a model industry example for in-circuit test as well as for final functional testing of a BGA type device.

1) Overall Tester Requirements and Design

As explained in the introduction, the main functional requirements for the tester is to quantify linearity performance of the detector module. In addition, the tester also checks for signal connectivity as well as "dark" (no injection) testing of the electronics. The key tester requirements can be summarized below, a legend is provided for nomenclature definition.

MSM/MCM	Mixed-Signal Module/Multi-Chip Module
MCDC	Mercury Condensed Data Chain
DMM	Digital Multi-Meter
VCS	Vyper Chip Set (Digital Board)
TEC	Thermo-Electric Cooler

Table 1. Tester Requirements

Requirement	MSM Tester Requirement	Specification	Description / Origin	Design Met
1	Connectivity to ASIC (512 ch)	100%	Basic electrical requirement	Yes, precise pogo-pin solution
2	Temperature Control during Linearity Test	+/-2C	Based on best estimates from EE team	Yes, capable of supporting TEC for thermal control
3	Signal Injection throughout dynamic range	300pA – 350nA	Specification from literature search	Yes, capable of 100pA – 650nA+
4	Consistent and repeatable clamping force for ASIC contacts	60+ lbs clamping force	Pogo-pin clamping force required	Yes, Motor control available

Below is a summary of the tester block diagram showing the entire signal chain of the detector for the injection tester.

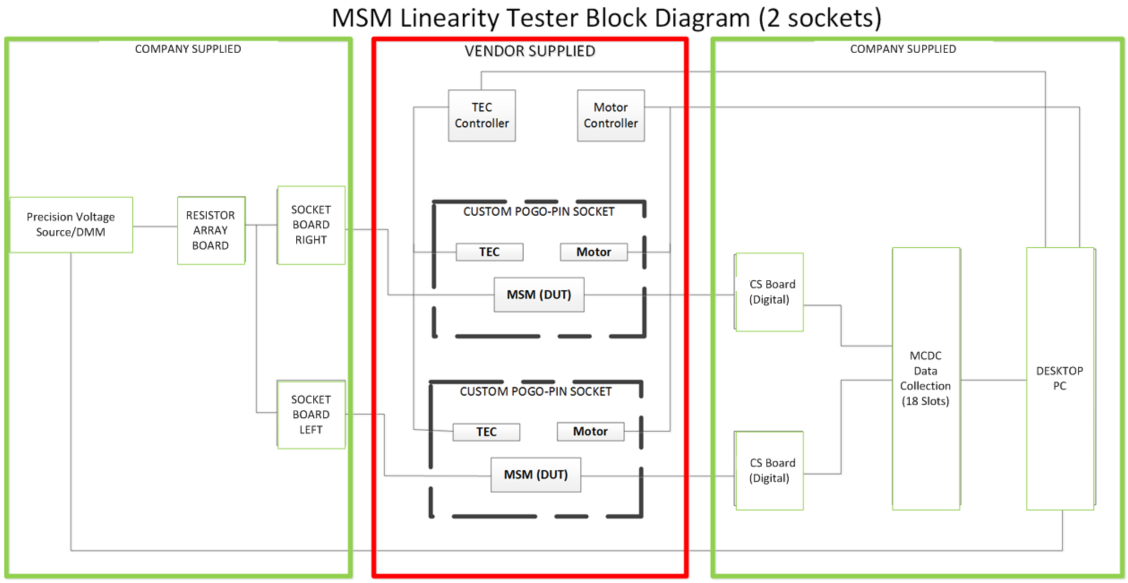


Figure 1. Tester Block Diagram

The complete test system is shown below (CAD & actual tester shown)

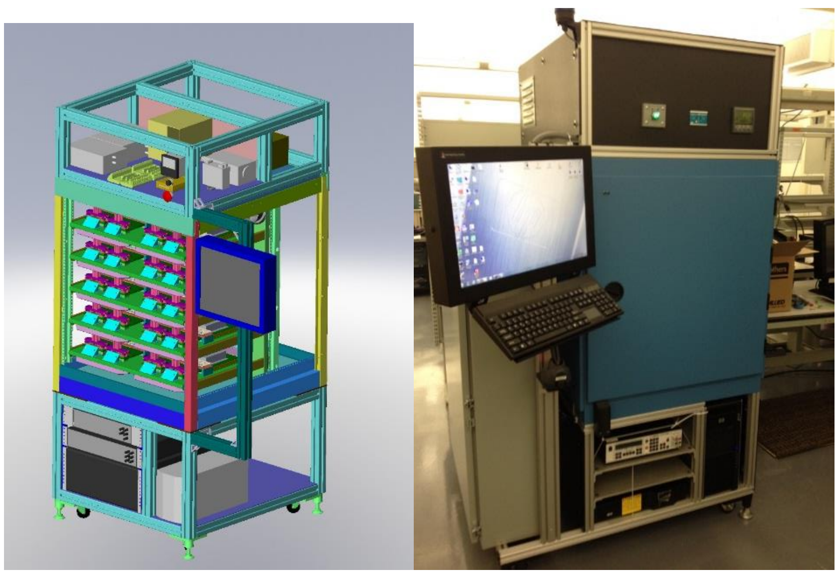


Figure 2. Picture of Complete Test System

The key components of the test system can be outlined below:

1) Precision Voltage Source → signal injection source
2) Resistor board and socket boards → spread the injection source to the various detector channels and set the overall injection current
3) Socket design → vendor supplied pogo-pin socket that utilizes a gear system to drive the pogo-pins between the socket board and the DUT (device under test)
4) CS board & MCDC Data collection → Digital data collection that collects the DUT data and sends to the PC for further processing
5) Desktop PC → Main PC for signal processing and graphical interface

The CAD design of the Resistor boards and socket design can be shown below:

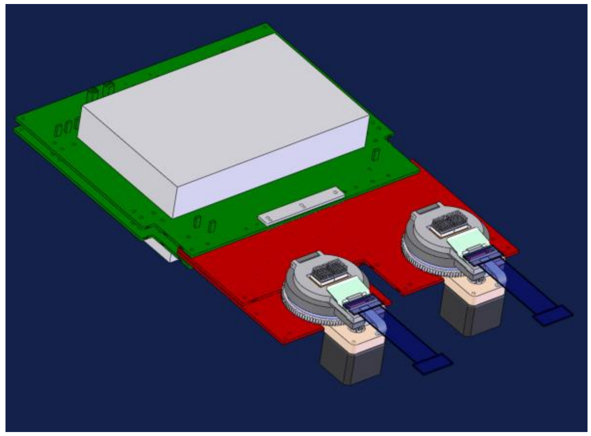


Figure 3. Socket board and test socket in CAD

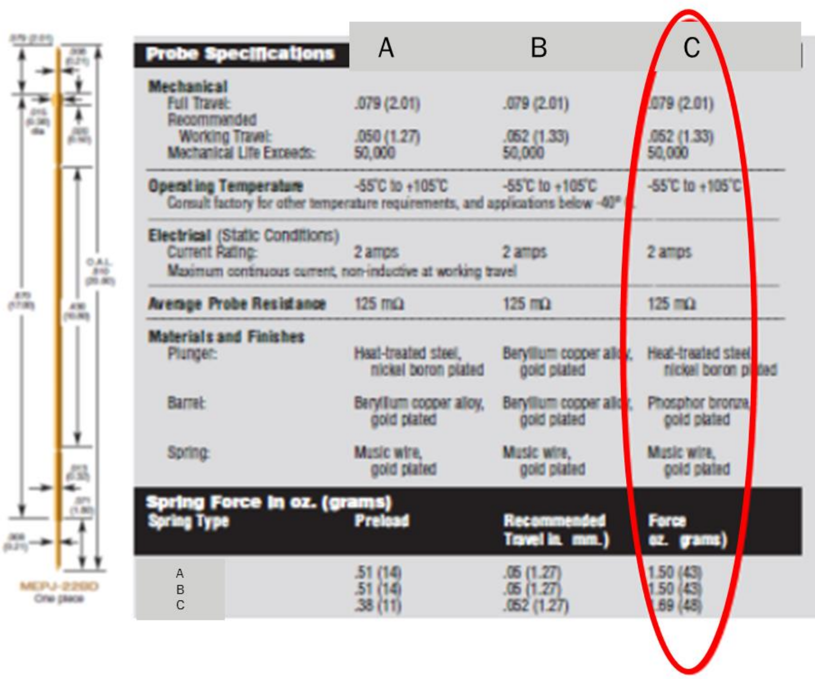
This paper and presentation will focus on the socket design challenges and also key learnings from the design that can be applied to general test systems, including reliability testing. The secondary focus will be on the overall data collection and graphical user interface for the test equipment.

The main design challenges covered in the paper will be the following:

1) Pogo-pin design and pogo-block design
2) Mechanical Design Considerations
    a. Socket Mechanical Design to Drive the pogo-pins
    b. Interconnection of a flexible circuit onto the DUT through a blind insertion
3) Socket reliability considerations
4) Software Graphical User Interface (GUI)

2) Pogo-pin design and pogo-block design

The pogo-block and related pogo-pins are the critical feature of the tester design, as they interface between the socket boards and the DUT. The following pogo-pin was selected because of the tall size and the superior electrical performance. To meet the low-signal linearity, a low-inductance connection method is required for the entire signal chain.



Probe Specifications	A	B	C
Mechanical			
Full Travel:	.079 (2.01)	.079 (2.01)	.079 (2.01)
Recommended Working Travel:	.050 (1.27)	.052 (1.33)	.052 (1.33)
Mechanical Life Exceeds:	50,000	50,000	50,000
Operating Temperature	-55°C to +105°C	-55°C to +105°C	-55°C to +105°C
Consult factory for other temperature requirements, and applications below -40°			
Electrical (Static Conditions)			
Current Rating:	2 amps	2 amps	2 amps
Maximum continuous current, non-inductive at working travel			
Average Probe Resistance	125 mΩ	125 mΩ	125 mΩ
Materials and Finishes			
Plunger:	Heat-treated steel, nickel boron plated	Beryllium copper alloy, gold plated	Heat-treated steel nickel boron plated
Barrel:	Beryllium copper alloy, gold plated	Beryllium copper alloy, gold plated	Phosphor bronze, gold plated
Spring:	Music wire, gold plated	Music wire, gold plated	Music wire, gold plated

Spring Force in oz. (grams) Spring Type	Preload	Recommended Travel in. mm.)	Force oz. grams)
A	.51 (14)	.05 (1.27)	1.50 (43)
B	.51 (14)	.05 (1.27)	1.50 (43)
C	.38 (11)	.052 (1.27)	1.69 (48)

Figure 4. Pogo pin design specifications

The pogo-pin is inserted in the pogo-pin block, as shown below:

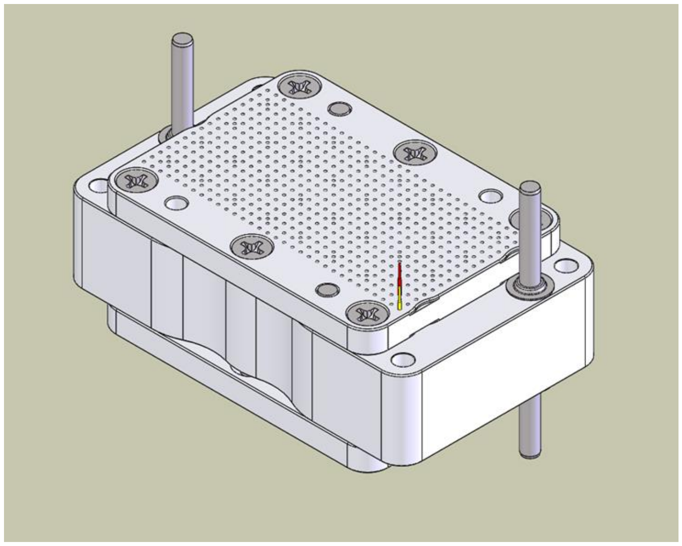


Figure 5. Pogo-block overall design

The pogo-block assembly shown is composed of 3 main components. This design was chosen to minimize design complexity of the top and bottom pieces; the center spacer block is a very simple part that takes up the majority of the pogo-pin length. Based on this design, the pogo-pins can only be inserted from one direction as there is a shoulder feature to prevent further travel.

1) Top block with precise holes defined per detector module spacing → shoulder feature to prevent further travel.
2) Center space block → clearance holes
3) Bottom block with precise holes defined per detector module spacing

Initial testing of the first revision pogo-block (PTFE) showed a significant material warpage issue that caused missing connections. This resulted in a material design change from PTFE to a stiffer plastic material, addressing the material warpage issue.

3) Mechanical Design Considerations

A motor driven planetary gear system was chosen as the leading design concept for the injection tester. This type of design was chosen to address the large amount of force required and to ensure even compression of the pogo-pins onto the DUT. This design also enabled ease of insertion/removal of the DUT into the socket as well as adjustable force applied through motor control. Further benefits included a scalable design to test multiple DUT's and the capability of a thermal control interface (not implemented but supported by the design.)

Below is a pictorial view of the tester socket cross-section showing the motor and gear system. The gear ratio was optimized for the design. Key features of this design include:

- Lid with handle and control sensors that detect the presence of the part and closure of the lid
- Clearance pocket for the pogo-block that allows for easy removal of the block for maintenance
- Allowance for a thermal control solution (heat sink shown in this picture)
- Screen below the DUT that protects the pogo-pins from dust/debris.

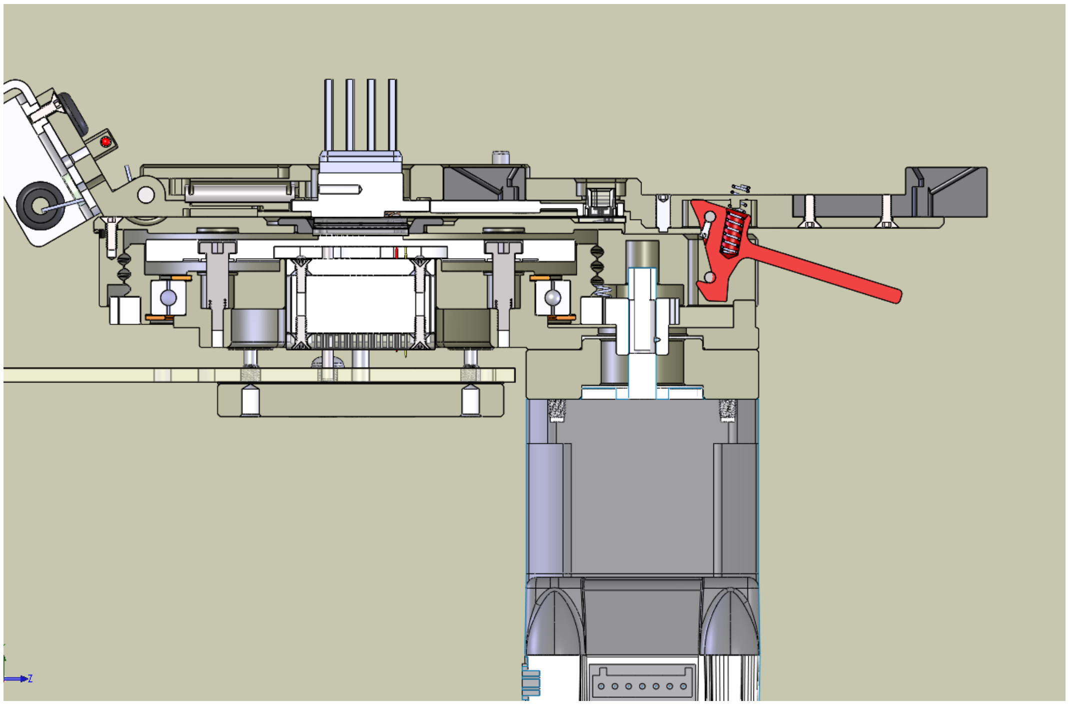


Figure 6. Tester socket cross-section

Another important feature of the test socket is the ability to handle a flexible circuit installation into a connector that is not visible. A dual mechanism was developed to facilitate in flex insertion and then subsequent latching of the cam latch on the DUT. This mechanism self-aligned to the existing socket and allowed for easy insertion and connection of the DUT to the rest of the test system.

A pictorial view of the latching system is shown below, with and without lid cover to expose the detail:

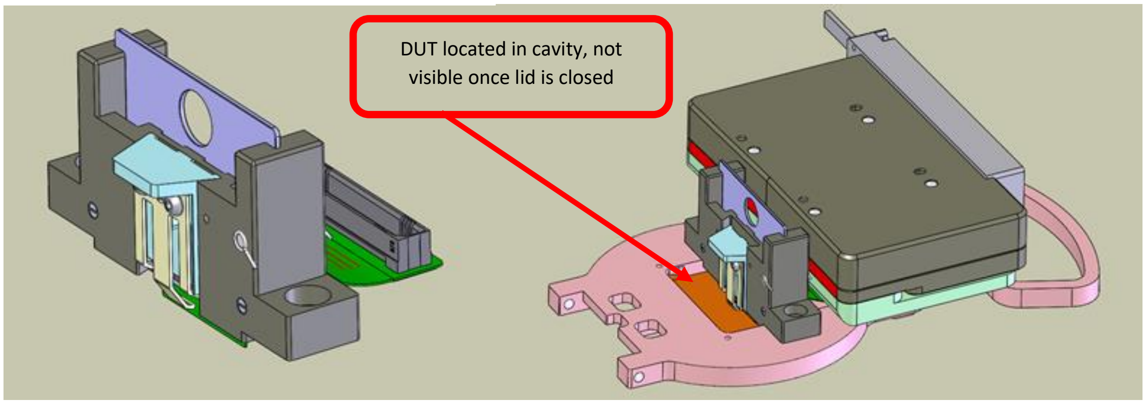


Figure 7. Tester socket flex insertion feature

4) Socket Reliability

A significant risk to the design was the socket cyclical life during the continued use of the tester. Below is a snapshot of the tester expected number of cycles.

MCM Injection Tester Socket Calculator			
Test Sequence	Trim	0.2	min
	Calibration	0.2	min
	Offsets	0.6	min
	Noise	0.6	min
	Linearity/Connectivity	1	min
	Leakage	0.6	min
	Test Time	3.2	min
	Load Time	1	min
	Unload Time	1	min
	Total Time	5.2	min
	# Sockets	4	
	MCM per hour	46.154	
	MCM per shift	276.923	
	MCM per week	2769.231	

Figure 8. Tester socket flex insertion feature

An engineering setup to manually control and cycle the motor was set up, enabling cycling of the motor to tens of thousands of cycles. During each cycle of the motor (up/down), data collection using a known test system was performed to check connectivity of each pogo-pin.

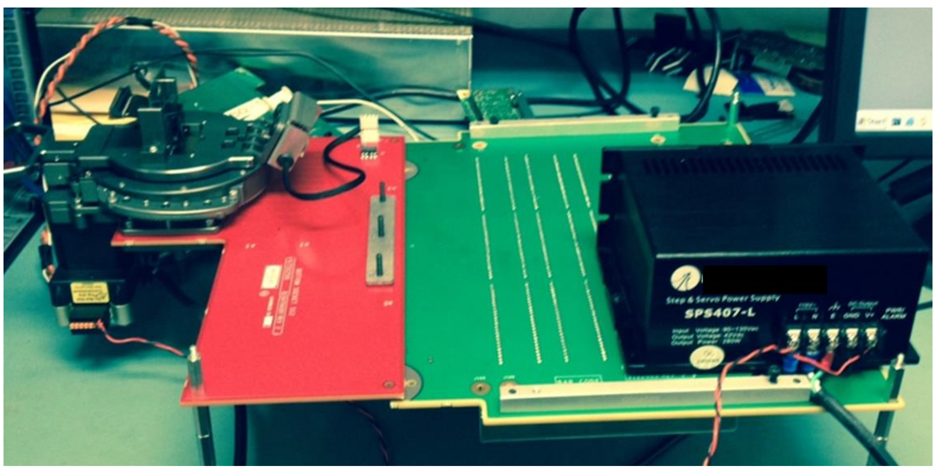


Figure 9. Tester socket motor cycling setup

Below are the results of the initial socket cycling experiments, the following 5 pixels shown were found to be repetitive failures. A closer examination of all 5 shows that these pixels are located on the edge perimeter of the DUT.

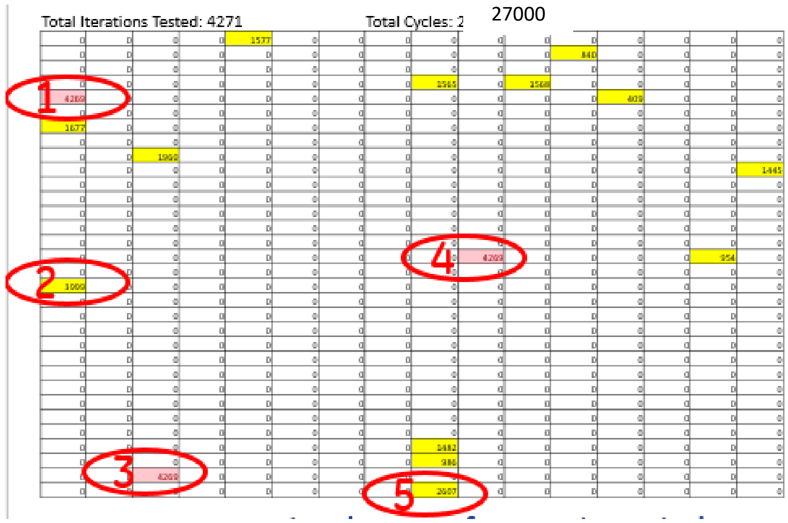


Figure 10. Failure map of pixels after socket cycling (27000 cycles)

Further examination of the pogo-pin mark (i.e. dimple pattern) revealed that the pogo-pin dimple missed the edge pixels due to the reduced shape of the edge pad, shown below.

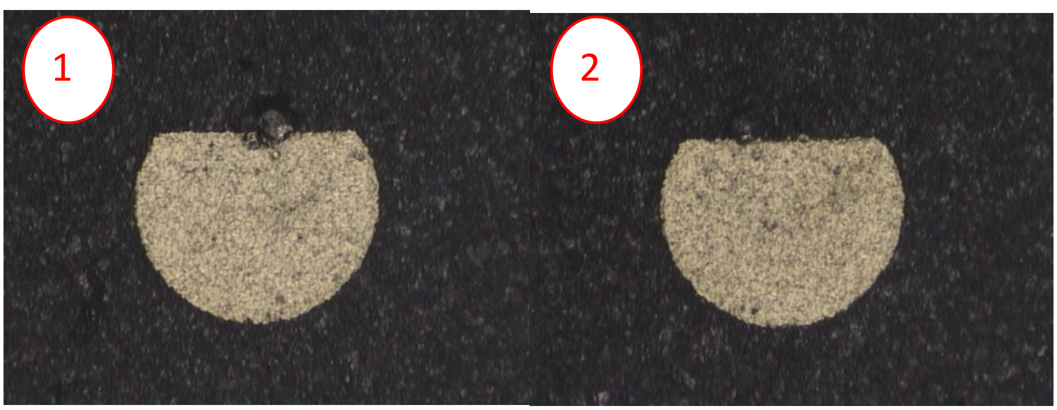


Figure 11. Dimple pattern of 2 sample pixels after socket cycling (27000 cycles)

This finding prompted two design changes:

1) Increase of the edge pads by the supplier to allow more margin for the connection
2) Offsetting of the edge pogo-pins to allow for better matching to the pad centroid

After these design changes were in place, the socket was tested and passed over 50,000 cycles without failure or mechanical degradation.

5) Tester Graphical User Interface

In addition to the connectivity and pogo-pin related tests, the injection tester also checks a number of dark current tests. This test sequence is controlled through a series of batch scripts, python scripts, and configuration files. The Graphical User Interface for the tester is shown below:

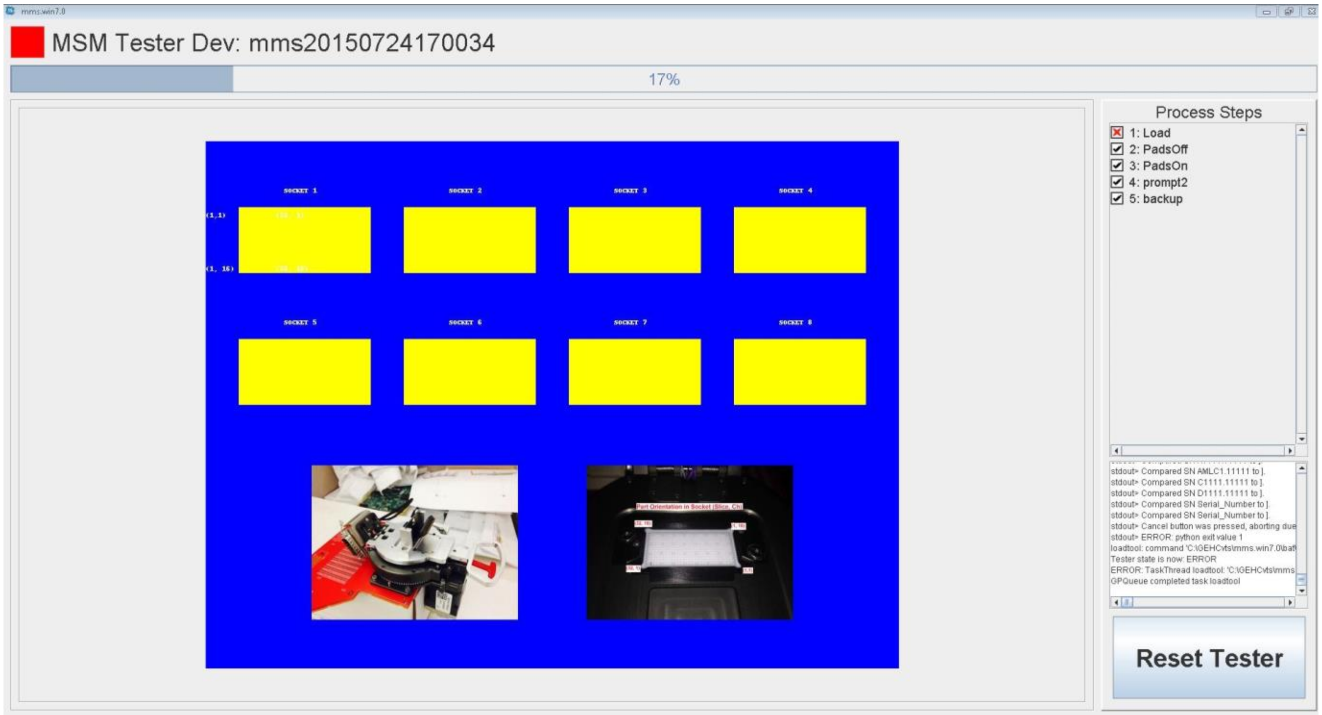


Figure 12. Tester graphical user interface

6) Conclusions

Overall the MCM injection tester had significant design challenges that were explored in this paper, including pogo pin design, socket mechanical considerations, and socket reliability. The concepts of an integrated pogo-block and motor driven gear socket assembly can be leveraged for test systems that need precise alignment and consistent force. In addition, reliability aspects of the test socket were explored in detail, showing the test system is capable of surviving over 60,000 cycles. Lastly, the tester graphical user interface was shown to outline how the overall test sequence behaves. This test system can be used as a model example for other equipment manufacturers who face similar high density signal interfaces that require precise alignment and accurate clamping.