Test Report  
Total Ionizing Dose (TID) Testing of the  
Philips SA8016DH, 2.5GHz Low Voltage Fractional-N Synthesizer  

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I. Introduction  
The Philips SA8016DH, 2.5GHz Low Voltage Fractional-N Synthesizer is a BiCMOS process technology device. The SA8016 device integrates programmable dividers, charge pumps and a phase comparator to implement a phase-locked loop. The device is designed to operate with low current and nominal 3 - 5 volt supplies. The synthesizer operates at VCO input frequencies up to 2.5 GHz. The synthesizer has fully programmable main and reference dividers. All divider ratios are supplied via a 3-wire serial programming bus. Separate power and ground pins are provided to the analog and digital circuits.  

II. Device Tested  
The device tested is the Philips SA8016DH BiCMOS, 2.5GHz Low Voltage Fractional-N Synthesizer. The five devices to be tested are from the Lot-Date-Code (LDC) C04132, the same LDC as SEE testing and for the project hardware. Complete package markings for the devices are:  

<table>
<thead>
<tr>
<th>SA8016</th>
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<tbody>
<tr>
<td>C04132</td>
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<tr>
<td>F n 030</td>
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<td>3 B</td>
</tr>
</tbody>
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III. Test Facility and Conditions  
NASA GSFC’s low doserate Cobalt-60 irradiator was used for these tests.  
**Dose Rate Target** = 10 mRads (Si)/s  
**Test (Vcc) Voltage:** 5.0 Volts  
**F_{Main} = 2.15 GHz, F_{Ref} = 40 MHz**  
**Temperature = room**  

IV. Test Methods  
Five SA8016 DUTs were irradiated at the same time. During irradiation the DUTs did not run closed-loop as they would during flight (or any other actual operation) but
open-loop. They were all powered, programmed, and exercised with approximate signals at their Fref and Fmain inputs during irradiation. First knowledge of functionality was gathered open-loop in-situ (during irradiation), but occasionally during the test irradiation was stopped and each DUT was operated closed-loop to verify that it did, indeed, lock and operate at the correct frequency.

Test Hardware Description

The five DUTs resided on one single-layer (plus ground plane) etched board. Each DUT had its own support circuitry, VCO control voltage (PHP) input, standby (PON) input, reference frequency (Fref) input and main frequency (F\text{\textsubscript{Main}}) input connections (See Figure 1). During irradiation, the F\text{\textsubscript{Main}} connections were bussed to provide an exercising signal to all of the DUTs. The DUTs were not in actual phase or frequency lock during their open-looped state for irradiation, but could be monitored to determine roughly correct operation. Irradiation was interrupted to conduct closed-loop testing to verify proper operation.

Figure 1  SA8016 TID Board showing five DUTs. Connectors are mounted on flip side.
Refer to Appendix A, a .pdf of the SA8016 TID Test Block Diagram and Appendix B, a .pdf of the SA8016 TID Board Schematic. The irradiation board holding the 5 DUTs with their support circuitry is shown shaded grey.

One common Fmain connection to the board provided distribution of an exercising signal of 2.15 GHz to all 5 DUTs by way of an isolated by a 1:5 RF splitter. In this way, when one DUT was operated individually the others did not affect loading or the RF characteristics of the path to the operating DUT. Each DUT circuit had its own SMA connector for Fmain input during individual operation.

Likewise one common Fref connection to the board distributed the reference frequency to all 5 DUTs (except that Fref was never not fed to all 5 DUTs at the same time so they did not have separate connectors).

Power was distributed to all 5 DUTs thru current sampling resistors. Individual DUT signals monitored were the power supply current measuring shunt resistor differential voltage, the DUT LOCK output signal and the integrated DUT VCO control voltage (Vvco).

During irradiation only the irradiation board resided within the Co-60 radiation. Cabling carried power (RG-58 coaxial cable), programming signals (ribbon cable), Fref and Fmain signals (high frequency Coaxial Cable) to the DUT and bundled twisted-shielded differential pairs brought the monitored signals out of the chamber for measurement.

Equipment used in this test included the PXI mainframe (described more, below), a quad channel power supply, and two RF signal sources, all connected by GPIB. In addition, a VCO module provided the last functional block necessary for closed-loop operation.

The VCO module contained the same type of VCO used in the single-event testing of this part. It had SMA connections for VCO control voltage (Vvco) input, VCO module power input and two 6-db split main frequency (Fmain) outputs. In use, one Fmain output fed the DUT circuit and the other was used to monitor closed-loop frequency output. The VCO module was never irradiated.

Test Control and Test Software

Appendix A shows the PXI Mainframe-enclosed Controller PC used for this test. PXI is a chassis physical and electrical standard very similar to cPCI. The controller PC was a multi-slot module that slid into the mainframe, connecting to the PCI bus. The controller ran a Windows operating system with Labview (LV) programming environment with a custom-written application for the SA8016 TID test. The LV app controlled the multimeters, switch matrix, Digital Input/Output (DIO) and GPIB
interface modules in the PXI mainframe. Figure 2 shows the front panel of the LV app.

![Figure 2. Screenshot of the Labview App used to control equipment and gather data.](image)

Operation of the test setup for irradiation involved the following steps:

- Making all connections and powering the equipment. The DUTs at this point were not powered up. If one DUT was to be operated closed-loop then the VCO module was connected to it. Else, the Fmain signal was fed to all DUTs.

- Selecting each DUT’s hardware jumper for On or Standby (this could be done either before or after the step listed next, powering up the DUTs)—One DUT On for closed-loop testing, all DUTs on for irradiation;

- Powering the setup with DC power and RF signals in the correct order.

- Programming the DUT(s) with configuration data. After this the DUT(s) should have been operational.

When the DUT was operated closed-loop to determine whether it locked to the correct frequency, the VCO output frequency (Fmain) was measured. When the DUTs were irradiated an RF signal generator signal was fed to all 5 DUTs’ Fmain inputs.
During irradiation in order to gain a rough measure of functionality the frequency of
the Fmain signal was set above, and then below, the nominal precise locked frequency
prescribed by the DUT configuration settings. Due to the nature of the loop transfer
function, any even infinitesimal frequency difference between the nominal and the
actual Fmain frequencies would result in the VCO control voltage, Vvco, running to one
extreme of its range or the other (0 and 5 Vdc). Thus, by setting the RF signal generator
to a few KHz below and then above the nominal frequency the DUT could be judged to
be probably functional or definitely unfunctional.

V. Findings

Irradiation Schedule

Irradiation occurred with short breaks, both for the purpose of conducting closed-loop
testing on these devices and due to other facility requirements (daily safety checks,
other DUT insertions/extractions, etc.) so the dose rate times the total time in the
irradiator do not equal the accumulated dose (it will be higher than actual accumulated
dose).

<table>
<thead>
<tr>
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<th>(rad/min)</th>
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<th>TID</th>
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<td>6.49 Krad</td>
<td>6.49 Krad</td>
</tr>
<tr>
<td>5:20PM</td>
<td>1:20PM</td>
<td></td>
<td></td>
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</tr>
<tr>
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<td>9/11/07</td>
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<td>3.62 Krad</td>
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<td></td>
<td></td>
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<tr>
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<td>5.89 Krad</td>
<td>15.99 Krad</td>
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<tr>
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<tr>
<td>5:01PM</td>
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Nominal DUT behaviour

Nominally (see anomaly description, below) there was no change in performance over
the course of the entire test:

One DUT circuit of the 5 on the irradiation board was not functional from before
irradiation. It is uncertain what the cause of that problem was. Testing was performed
with all five DUTs but obviously the one was ignored. Its malperformance did not
affect the rest of the DUTs. The other four DUTs performed correctly at all times.

At start of irradiation, while functioning, the individual DUT circuits drew
approximately 11 mA each, and the combined supply current for all 5 DUTs was 55.6
mA. At end of irradiation the individual and combined currents were essentially unchanged at about 11 mA and 56.0 mA total. The unfunctional DUT drew the same current as the other DUTs.

Anomaly

Anomalous behaviour was observed at two points during the irradiation but it was neither regular nor repeatable. At 2 day, 22 hr into the irradiation all DUTs dropped current consumption and Vvco output voltage dropped from the nominal 4.6 Vdc to about 0.63 Vdc. Upon reconfiguration the DUTs performed perfectly nominally and the anomalous behaviour could not be reproduced. (It was not noted in the log file whether power cycling also occurred; if it was, the reconfiguration would probably not have been noted as such but instead would be presumed as part of the power-on sequence. The conclusion is that power cycling was probably not part of regaining DUT operation but possibly did occur.)

It was noted that several closely spaced irradiator shutter closings and openings occurred right at the time when the anomaly occurred. No connection between the anomaly and the irradiator operation could be made. Speculatively, personnel may have disturbed the test setup. A DC power interruption would have resulted in a configuration loss as was observed.

In response to this, the test control program was modified in order to periodically change the Fmain exercising input signal frequency between just under and just above Fnom; Vvco was monitored for each case. In this way the functionality of the DUT was verified at the measurement interval, which was about 15 minutes. The rest of the testing occurred with this additional set of measurements included.

Again during an irradiation, at 2 days, 21 hr, during a period of frequent shutter operation the anomaly recurred. At about 16 Krad all DUTs recovered with a reconfiguration *without* power cycling. The coincidental elapsed times (within 2% of each other) prompted a theory that the anomaly was related to elapsed time of operation in radiation.

In response to this an extended period of irradiation was commenced and near 3 days the operation was closely noted. However, by 8 days no anomaly was noted and the irradiation was terminated. It is emphasized that the second anomaly also occurred during frequent shutter cycling.

Both times the DUTs lost operation all four functioning DUTs lost operation in the same measurement interval. This observation lends credence to the theory that it was an external event such as power supply interruption and not TID-related failure that caused the anomalies.
The simultaneous nature of the anomalies, the failure to otherwise identify possible causes, the failure to repeat the anomaly and the near-certain non-power-cycle recoverability of the anomaly prevented further investigation.

VI. Conclusion
If not for the occurrence of the anomaly these devices would have been documented to have suffered no detectable change in performance in over 25 Krad accumulated at low dose rate.

The unknown anomalousness which twice caused all four DUTs to simultaneously temporarily stop functioning, as if they became simultaneously unconfigured, was corrected at least once by reconfiguration without powercycle. All indications are that reconfiguration without powercycle corrected the anomaly both times. The anomaly could not be replicated a third time. The best guess is that the anomaly is not related to radiation at all but the irradiator shutter operation.

In conclusion the SA8016 of this LDC is recommended for use in TID environments to 15 Krad Si.
Appendix B - Schematic