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1 Executive Summary

The NT Lab NT1065 is susceptible to SEL, but with limits to the current supplied in the fault state, and the duration that the fault state is allowed to persist for, this need not be a hindrance to use in space. For further details see section 6.

Data is available for rate characterisation (see section 7).

To perform the tests a preconstructed RF signal provided the test stimulation and was monitored by an FPGA and MCU that checked the received data for errors. The test platform included the necessary local voltage regulation components to ensure the supply voltage stayed within data sheet limits (3.0V), and a CSL system was implemented to detect and limit supply current in the event of SEL. For these tests the current limit was set to 200mA. The tests were performed at an ambient temperature of approximately 25 Celsius, however when SEL occurs the temperature is expected to rise (the tests are performed in vacuum so heat transfer only used conduction through the PCB and radiation).

2 Component Description

Manufacturer's designation: NT1065
Manufacturer's name: NT Lab
Manufacturer's address: LT-09308 Vilniaus r., Lithuania
Package designation: QFN88
Component group: CMOS process
Datasheet reference: NT1065, rev. 2.19 July 2020

Device Date/Batch codes: 1816

"NT1065 is a four-channel RF Front-End IC for the reception of Global Navigation Satellite System (GNSS) signals (GPS, GLONASS, Galileo, BeiDou, NavIC, QZSS) and also signals of satellite-based augmentation systems like OmniSTAR at all frequency bands in various combinations: L1, L2, L3, L5, E1, E5a, E5b, E6, B1, B2, B3. Galileo E5 band as well as BeiDou B1, B2, B3 (phase 3) band can be obtained as entire signal with two channels fed by the same LO and then restored in digital domain to true complex data. As a benefit one can discover wide possibilities of improving the positioning accuracy down to centimeter range without taking RTK technique. Each setting, including output signal frequency bandwidth, AGC options, mirror channel suppression option, etc., can be set for every channel individually. NT1065 includes two fully independent frequency synthesizers. Channel#1 and channel#2 are supplied with LO signal generated in PLL "A" while PLL "B" is assigned for channels #3 and #4. For specific applications there is an option to feed all four channels with single LO source from PLL "A". This powerful toolkit is accompanied with very simple and easy-to-use register map. All the functionality allows application of NT1065 in high precision GNSS based positioning, goniometric, driverless car systems and related branches."

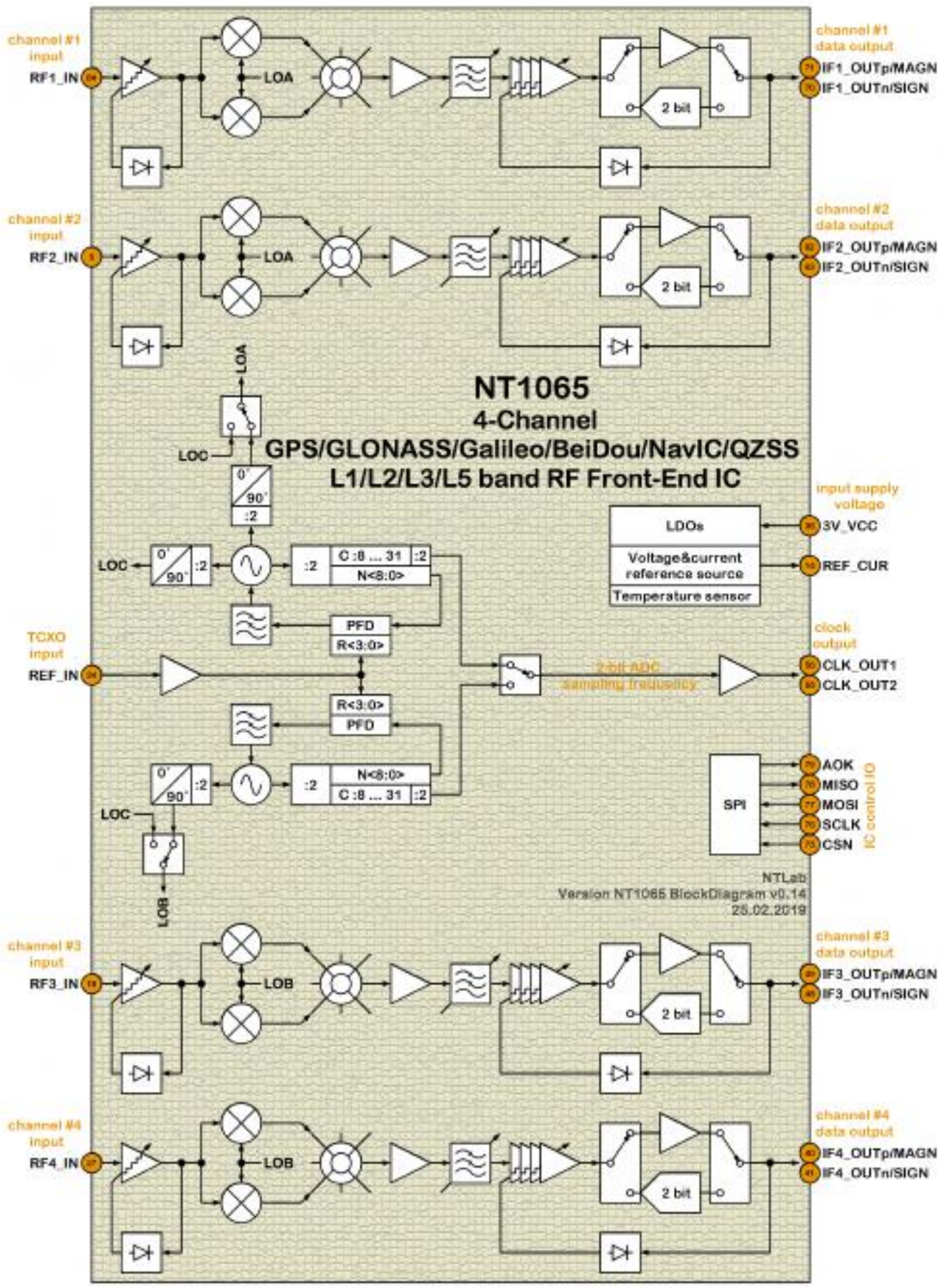

Figure 1. NT1065 Block Diagram

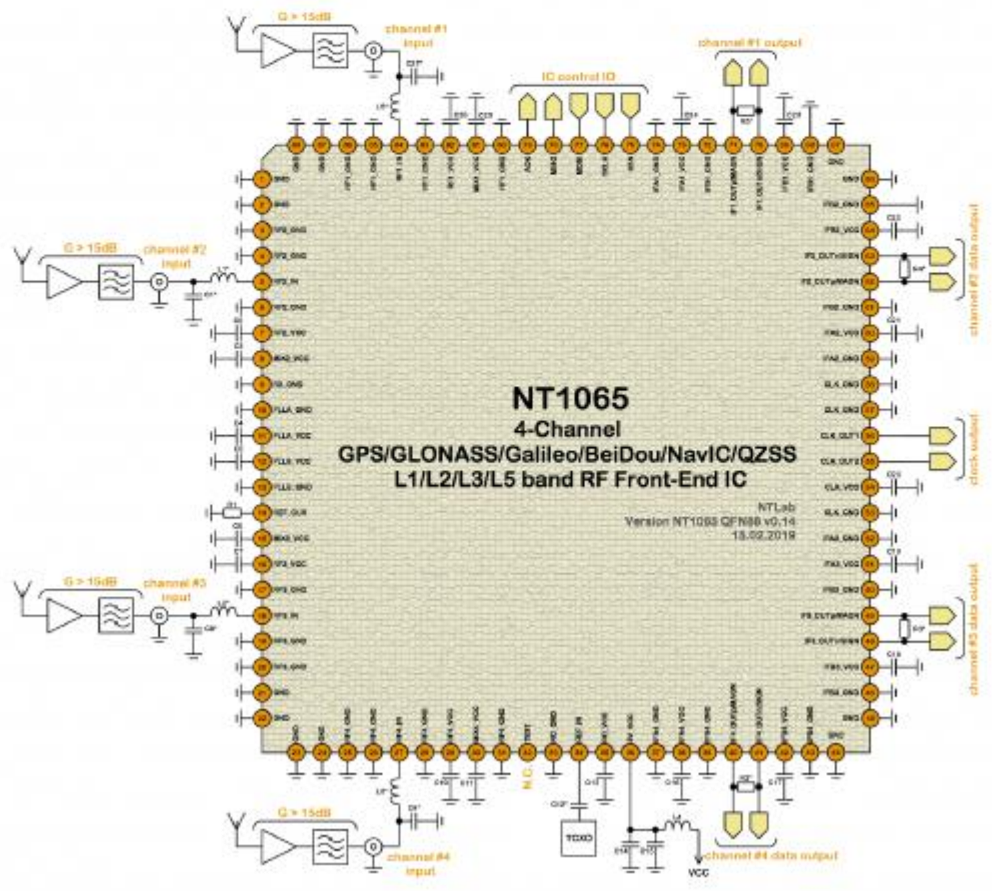

Figure 2. Typical Application Drawing.

3 Heavy Ion Test Facility

Heavy ion testing was performed at the Université catholique de Louvain (UCL) Heavy Ion Facility (HIF). Exposures are performed in vacuum. The facility provides one beam cocktail at 10 MeV/u. The specific species as well as their range in silicon and LET are shown in the table below.

Available particles inside the cocktail:

M/Q	Ion	DUT energy [MeV]	Range [µm Si]	LET [MeV/(mg/cm²)]
3.25	$^{13}C^{4+}$	131	269.3	1.3
3.14	$^{22}Ne^{7+}$	238	202.0	3.3
3.37	$^{27}Al^{8+}$	250	131.2	5.7
3.27	$^{36}Ar^{11+}$	353	114.0	9.9
3.31	$^{53}Cr^{16+}$	505	105.5	16.1
3.22	$^{58}Ni^{18+}$	582	100.5	20.4
3.35	$^{84}Kr^{25+}$	769	94.2	32.4
3.32	$^{103}Rh^{31+}$	957	87.3	46.1
3.54	$^{124}Xe^{35+}$	995	73.1	62.5

4 Results

The only type of effect seen was SEL. This was seen to be non-destructive.

The raw data for rate calculation is shown below.

Run # (UCL #)	Ion	Flux ($p/cm^2/s$)	Fluence (p/cm^2)	Result	Notes
2 (1)	Rh	500	5.72E+04	SEL = 20 (Blue board)	Configuration 2: Faster programming of FPGA
3 (2)	Rh	500	3.25E+04	SEL = 20 (Green board)	Configuration 2
4 (3)	Cr	2000	1.00E+06	SEL = 3 (Green board)	Configuration 2
5 (4)	Cr	2000	1.00E+06	SEL = 3 (Blue board)	Configuration 2
6 (5)	Ni	2000	6.23E+05	SEL = 20 (Blue board)	Configuration 2

Cross-sections have been calculated for the various species used and have been tabulated below. Where multiple data is available (because both boards were tested) the figures have been combined.

Cross-sections (in cm^2) versus LET for SEL

Effect Type	LET = 16.1	LET = 20.4	LET = 46.1
SEL	3e-6	3.21e-5	4.46e-4

(any values shown as <1e-6 are based on an event count of 0).

The 7th run was performed to characterize the SEL. This took the form of a test where the latch-up condition is induced using Nickel ions, then the beam is stopped. In this state the power was still applied for a further minute. After that the board was power cycled and operation checked. A second test which was the same as the above but with a five minutes delay in the latched-up state was also performed.

When the above test was performed, both steps saw complete recovery after power was cycled. In the fault state, the current was seen to have risen by about 1.1A (the nominal current is normally below 100mA).

It is noted that the system circuit has an LDO to provide power to the NT1065 that reduces the 5.0V supply down to 3.3V. This regulator is rated at 1A and will have been limiting the output voltage during the tripped condition. It is not known what the supply voltage present on the NT1065 was, so the power dissipation in the regulator and the NT1065 cannot be determined individually, but collectively would have been 5.5W.

5 Shot Log

The table below lists all the runs performed.

Ion	Flux ($p/cm^2/s$)	Fluence (p/cm^2)	Board	Run # (UCL #)	Notes
Rh	1000	2.62E+04	Blue	1 (1)	Initial configuration. Flux too high, some events missed
Rh	500	5.72E+04	Blue	2 (1)	Configuration 2: Faster programming of FPGA
Rh	500	3.25E+04	Green	3 (2)	Configuration 2
Cr	2000	1.00E+06	Green	4 (3)	Configuration 2
Cr	2000	1.00E+06	Blue	5 (4)	Configuration 2
Ni	2000	6.23E+05	Blue	6 (5)	Configuration 2
Ni	2000	2.00E+05 (irrelevant)	Blue	7 (5)	Configuration 2 Latch-up Characterisation

It is important to note that we operated the shutter for the beam, thus there is not direct correlation between our test runs and those logged by UCL.

6 Mitigation

It is not possible to prevent SEL occurring, but if the current delivered to the NT1065 while in the fault state can be limited to 1.1A or lower, the device will recover full operation once the power is cycled.

From this, it is clear that use in space requires two things. First, the maximum current supplied to the device should be below 1.1A (given that the normal operating current is less than 0.1A, this should not be hard to do). And second, the circuit needs to have the ability to turn off the power to this device to restore operation.

7 Weibull Parameters

The Weibull parameters have been generated using the Omere software.

Function	W	S	Limit Cross Section	LET Threshold
SEL	18.4	3.18	4.46e-4	12.3