INSPIRE-SAT 7

Preliminary Design Review

SPINO Amateur Radio payload - Electronic board definition

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Introduction

- **A strong Amateur Radio community / LATMOS partnership**
  - Enthusiats involved in non-profit / educational space projects decided to design a full « libre » (open source) bidirectional telemetry board for cubesats : SPINO

AMSAT Francophone

Electrolab : : HACKERSPACE

  - Such a project needs an « in-flight » validation to be seriously considered as a proper solution...
  - Motivated by the support that the amateur radio community has offered for UVSQ-SAT (data collection, support for the ground segment, support on spectrum coordination…), LATMOS has proposed to integrate this experimental board on UVSQ-SAT+ as an additional payload
- **Academic and industrial support**

LATMOS

Adrelys

Introduction

Amateur Radio telecom board :

- **Will be a pre-validated open source brick available off the shelf**
- **Maximize compatibility**
  - ✓ simple interface (UART, I2C, SPI, CAN FD)
  - ✓ PC-104 « like » form factor
- **Maximize reliability**
  - ✓ wide supply voltage range
  - ✓ Fail-safe on key points
  - ✓ Master the power consumption (especially in idle to face failure situations).
- **Operates in the Amateur Radio service bands**
  - ✓ VHF : TX (+30dBm) and RX 144-146MHz
  - ✓ UHF : TX (+30dBm) and RX 430-440MHz

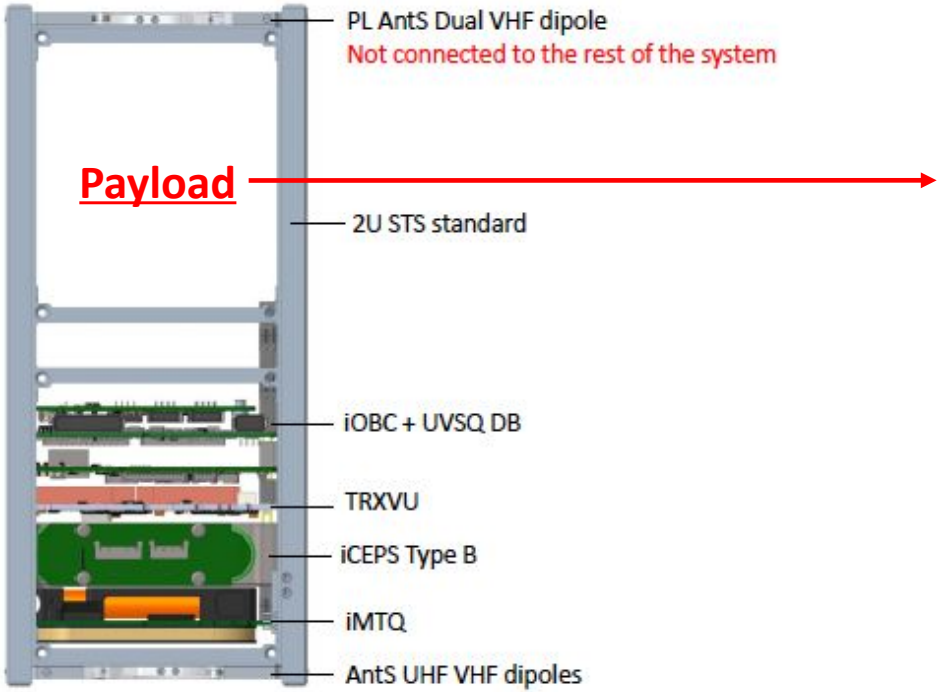
Introduction

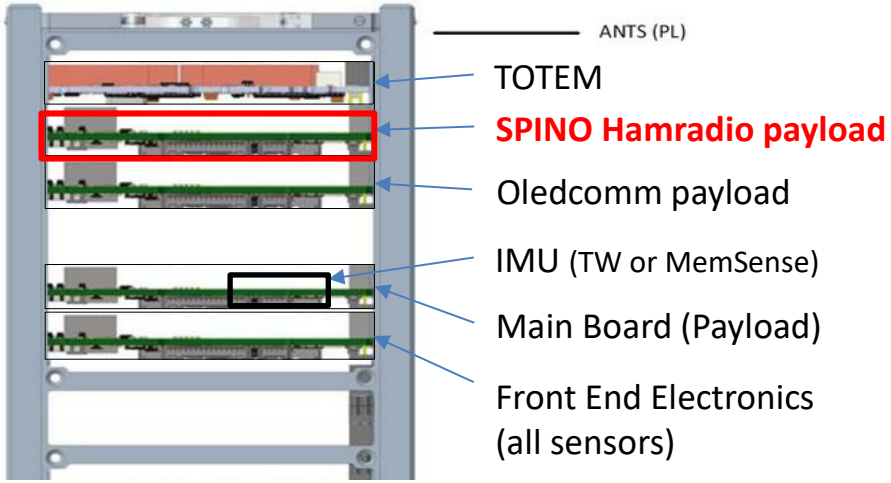
- **Tested as an independant radio system !**

  → Amateur Radio payload has its own frequencies (seprate spectrum coordination)

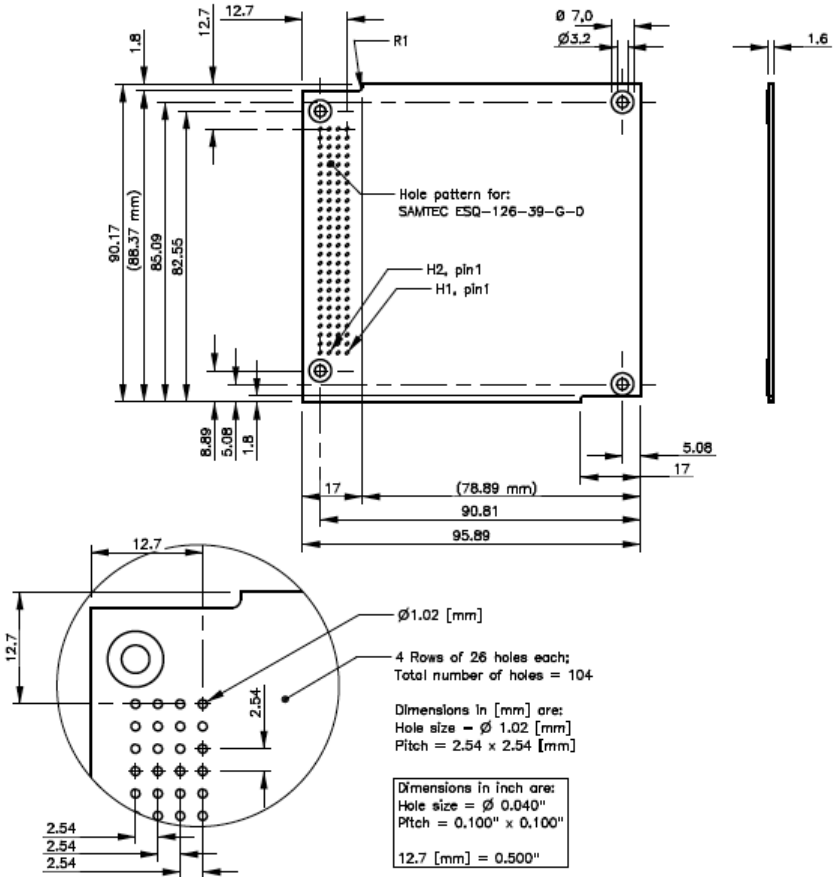
- **« low cost » efficient modulation support**
  - ✓ 2GFSK 600, 1200, 2400bps
  - ✓ 4GFSK 4800 (9600bps), 6400 (12,8kbps)
  - ✓ BPSK with G3RUH scrambling compatibility at downlink...
- **Features**
  - ✓ Managed or Autonomous beacon (support for OBC failure)
  - ✓ Data stream (uplink an downlink)
  - ✓ Antenna deploy support ← Not tested during this mission
  - ✓ Digital transponder
  - ✓ Digital mailbox
  - ✓ CMD from ground...

Inside the Cubesat

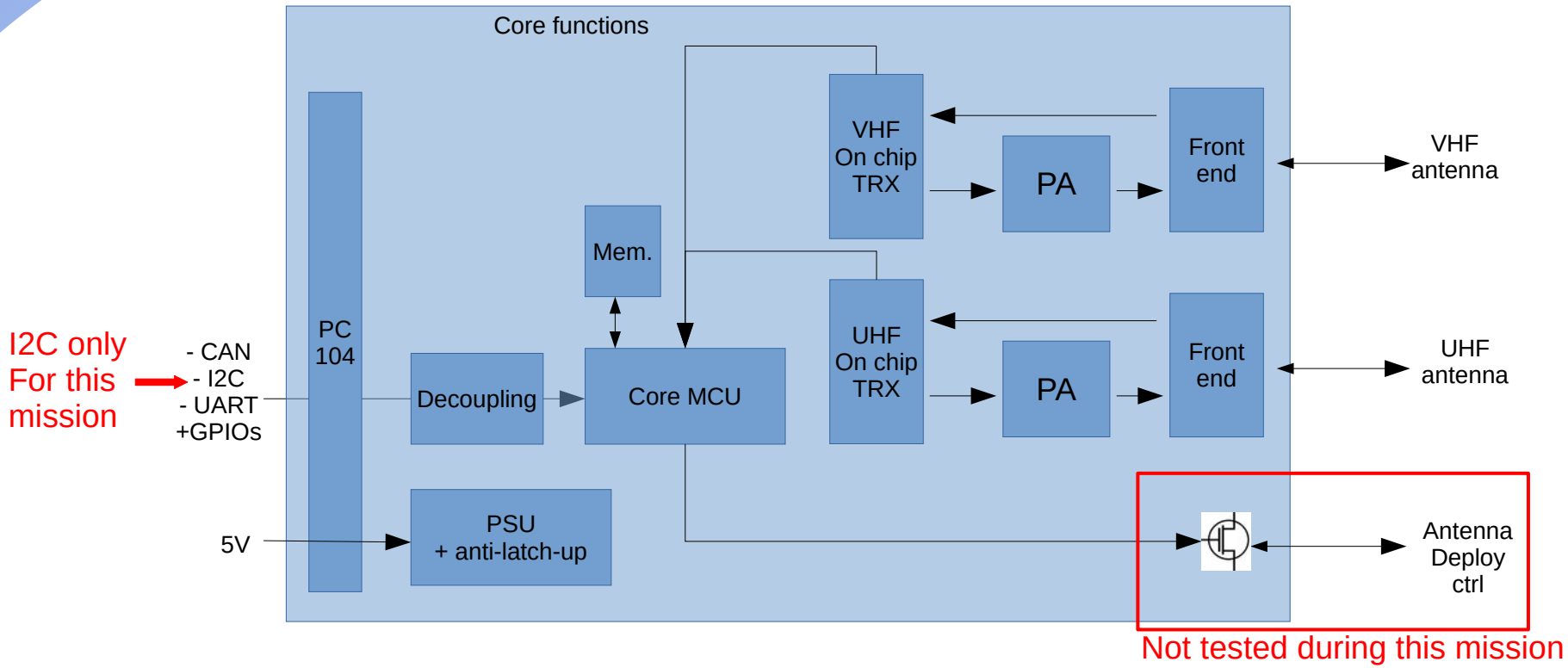




Form factor

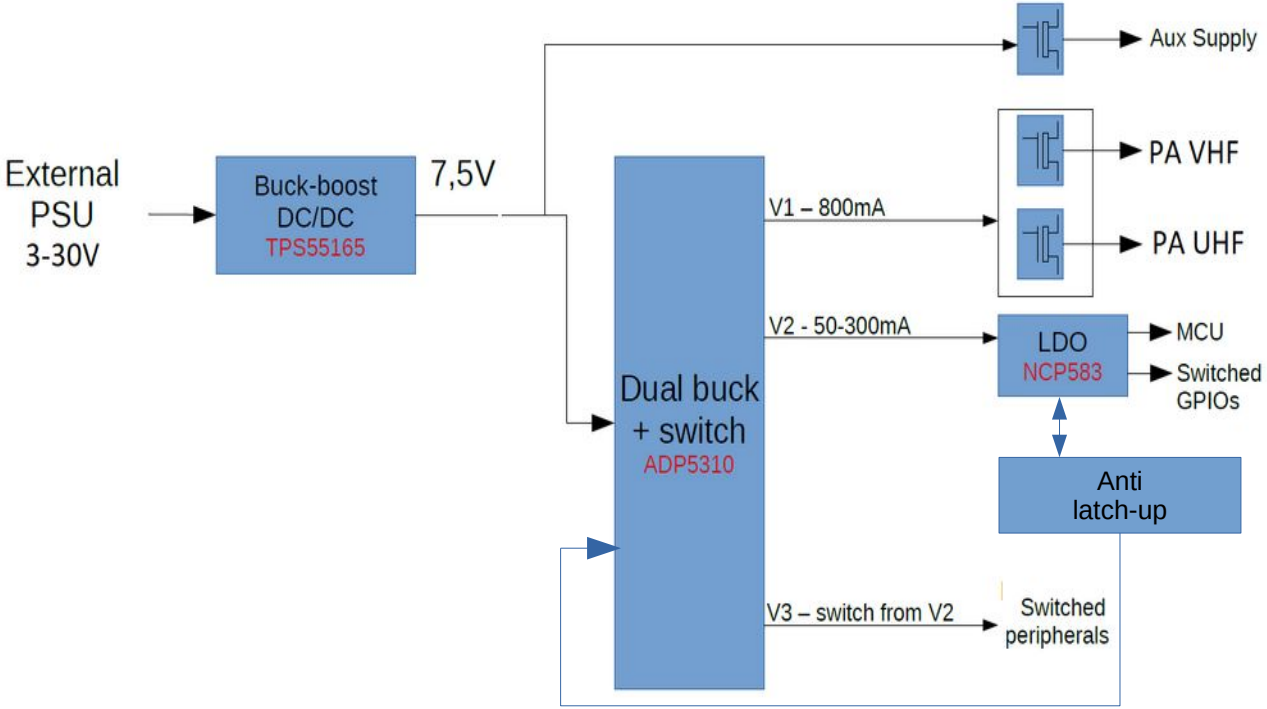

12.7
12.7
1.8
R1
Ø 7,0
Ø3.2
1.6
Hole pattern for:
SAMTEC ESQ-126-39-G-D
H2, pin1
H1, pin1
90.17
(88.37 mm)
85.09
82.55
8.89
5.08
1.8
5.08
17
17
(78.89 mm)
90.81
95.89
12.7
12.7
Ø1.02 [mm]
4 Rows of 26 holes each;
Total number of holes = 104
2.54
Dimensions in [mm] are:
Hole size = Ø 1.02 [mm]
Pitch = 2.54 x 2.54 [mm]
Dimensions in inch are:
Hole size = Ø 0.040"
Pitch = 0.100" x 0.100"
12.7 [mm] = 0.500"
2.54
2.54
2.54

SPINO Block diagram



Core functions

Power supply



Core functions

MCU

life.augmented

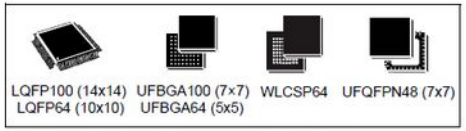
STM32L451xx

Ultra-low-power Arm® Cortex®-M4 32-bit MCU+FPU, 100DMIPS, up to 512KB Flash, 160KB SRAM, analog, audio

Datasheet - production data

Features

- Ultra-low-power with FlexPowerControl
  - 1.71 V to 3.6 V power supply
  - -40 °C to 85/125 °C temperature range
  - 145 nA in V_{BAT} mode: supply for RTC and 32x32-bit backup registers
  - 22 nA Shutdown mode (5 wakeup pins)
  - 106 nA Standby mode (5 wakeup pins)
  - 375 nA Standby mode with RTC
  - 2.05 µA Stop 2 mode, 2.40 µA with RTC
  - 84 µA/MHz run mode
  - Batch acquisition mode (BAM)
  - 4 µs wakeup from Stop mode
  - Brown out reset (BOR)
  - Interconnect matrix
- Core: Arm® 32-bit Cortex®-M4 CPU with FPU, Adaptive real-time accelerator (ART Accelerator™) allowing 0-wait-state execution



LQFP100 (14x14) LQFP64 (10x10) | UFBGA100 (7x7) UFBGA64 (5x5) | WLCSP64 | UFQFPN48 (7x7)

- Up to 83 fast I/Os, most 5 V-tolerant
- RTC with HW calendar, alarms and calibration
- Up to 21 capacitive sensing channels: support touchkey, linear and rotary touch sensors
- 12x timers: 1x 16-bit advanced motor-control, 1x 32-bit and 3x 16-bit general purpose, 2x 16-bit basic, 2x low-power 16-bit timers (available in Stop mode), 2x watchdogs, SysTick timer
- Memories
  - Up to 512 KB single bank Flash, proprietary code readout protection
  - 160 KB of SRAM including 32 KB with hardware parity check
  - Quad SPI memory interface

Core functions

VHF transceiver

SILICON LABS

Si4464/63/61/60

HIGH-PERFORMANCE, LOW-CURRENT TRANSCEIVER

Features

- Frequency range = 119–1050 MHz
- Receive sensitivity = –126 dBm
- Modulation
  - (G)FSK, 4(G)FSK, (G)MSK
  - OOK
- Max output power
  - +20 dBm (Si4464/63)
  - +16 dBm (Si4461)
  - +13 dBm (Si4460)
- PA support for +27 or +30 dBm
- Low active power consumption
  - 10/13 mA RX
  - 18 mA TX at +10 dBm (Si4460)
- Ultra low current powerdown modes
  - 30 nA shutdown, 50 nA standby
- Data rate = 100 bps to 1 Mbps
- Fast wake and hop times
- Power supply = 1.8 to 3.6 V
- Excellent selectivity performance
  - 60 dB adjacent channel
  - 75 dB blocking at 1 MHz
- Antenna diversity and T/R switch control
- Highly configurable packet handler
- TX and RX 64 byte FIFOs
- Auto frequency control (AFC)
- Automatic gain control (AGC)
- Low BOM
- Low battery detector
- Temperature sensor
- 20-Pin QFN package
- IEEE 802.15.4g compliant
- FCC Part 90 Mask D, FCC part 15.247, 15,231, 15,249, ARIB T-108, T-96, T-67, RCR STD-30, China regulatory
- ETSI Class-I Operation with SAW

Core functions

UHF transceiver

ANALOG DEVICES

High Performance, Sub GHz Radio Transceiver IC

Data Sheet **ADF7030-1**

FEATURES

Radio frequency (RF) ranges
- 169.4 MHz to 169.6 MHz
- 426 MHz to 470 MHz
- 863 MHz to 960 MHz

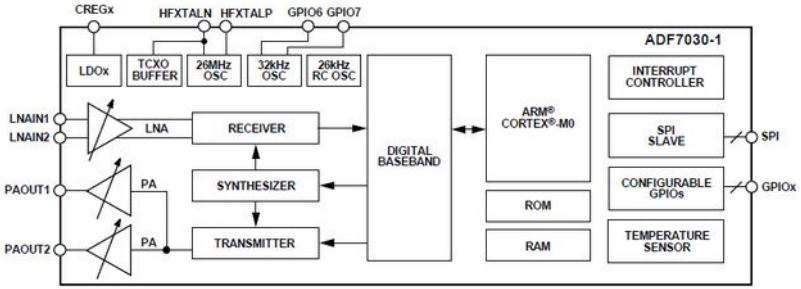
Data rates
- 2FSK/2GFSK: 0.1 kbps to 300 kbps
- 4FSK/4GFSK: 1 kbps to 360 kbps (transmit only)

Dual power amplifiers (PAs)

On-chip ARM Cortex-M0 processor for
- Radio control and calibration
- Packet management
- Clear channel assessment (CCA)

IEEE802.15.4g support
- Frame format
- Data whitening
- Dual-sync word detection
- Forward error correction (FEC) and interleaving

FUNCTIONAL BLOCK DIAGRAM



Core functions

Bandpass filters

Surface Mount

Bandpass Filter

50Ω 130 to 150 MHz

RBP-140+

Generic photo used for illustration purposes only
CASE STYLE: GP731

Features
- High rejection, 40dB typical
- Linear phase, up to ±7deg typical over Fc ±15MHz
- Good VSWR, 1.35:1 typical in passband
- Small size 0.35" x 0.35" x 0.1"
- Shielded case
- Aqueous washable

Applications
- Mobile application
- Space research
- Defence system
- Satellite

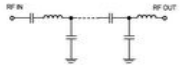
Electrical Specifications at 25°C

Parameter		F#	Frequency (MHz)	Min.	Typ.	Max.	Unit
Pass Band	Center Frequency	Fc			140		MHz
	Insertion Loss	F1-F2	130-150		2.6	3.5	dB
	VSWR	F1-F2	130-150		1.35	1.7	:1
Stop Band, Lower	Insertion Loss	DC-F3	DC-100	20	29		dB
	VSWR	DC-F3	DC-100		25		:1
Stop Band, Upper	Insertion Loss	F4-F5	178-3000	20	27		dB
	VSWR	F4-F5	178-3000		13		:1
Maximum Deviation from Linear Phase		Fc ±15MHz	125-155		±9	±14	deg

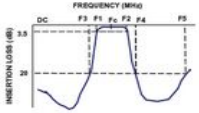
Maximum Ratings	
Operating Temperature	-40°C to 85°C
Storage Temperature	-55°C to 100°C
RF Power Input	0.3W max.

Permanent damage may occur if any of these limits are exceeded.

Functional Schematic



Typical Frequency Response



Typical Performance Data at 25°C

Frequency (MHz)	Insertion Loss (dB)	VSWR (:1)	Frequency (MHz)	Deviation from Linear Phase (deg)
1	81.53	7360.92	125.00	3.42
60	44.27	579.06	126.00	2.16
100	29.51	31.03	128.00	0.35
109	15.66	10.56	130.00	-0.73
114	8.73	4.20	132.00	-1.24
120	3.83	1.44	134.24	-0.97
125	2.66	1.16	134.44	-0.93
130	2.31	1.22	136.24	-0.62
140	2.23	1.34	138.24	-0.12
150	2.57	1.11	140.00	0.29
161	5.47	2.56	142.24	0.96
166	10.71	6.05	144.24	1.24
178	28.39	22.29	146.04	1.21
180	31.55	25.19	146.84	1.11
182	34.88	28.03	147.04	1.08
190	52.41	40.41	148.00	0.54
200	46.17	57.91	150.00	-0.30
600	85.00	289.53	151.00	-0.91
2200	65.48	31.60	153.00	-2.68
3000	55.39	26.33	155.00	-5.42

Metal Shield

Bandpass Filter

50Ω 410 to 470 MHz

RBP-440+

Generic photo used for illustration purposes only
CASE STYLE: GP731

+RoHS Compliant
The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications

Maximum Ratings

Operating Temperature	-40°C to 85°C
Storage Temperature	-55°C to 100°C
RF Power Input	0.5 W at 25°C

Permanent damage may occur if any of these limits are exceeded.

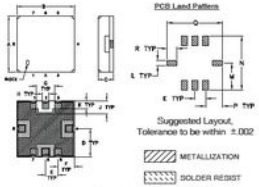
Pin Connections

RF IN	2
RF OUT	6
GROUND	1,3,4,5,7,8

Features
- linear phase, up to ±3deg typ. @ Fc ±30MHz
- good VSWR,1.3:1 typ. @ passband
- small size 0.35" x 0.35"
- shielded case
- aqueous washable

Applications
- harmonic rejection
- transmitters / receivers
- personal & home communication

Outline Drawing



Outline Dimensions (inch / mm)

A	B	C	D	E	F	G	H	J
.350	.350	.100	.175	.075	.100	.110	.040	.080
8.89	8.89	2.54	4.45	1.93	2.54	2.79	1.02	2.03

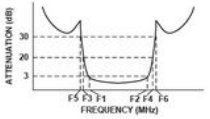
K	L	M	N	P	Q	R	wt
.050	.040	.195	.390	.120	.390	.070	grams
1.27	1.02	4.95	9.91	3.05	9.91	1.78	0.25

Note: Please refer to case style drawing for details

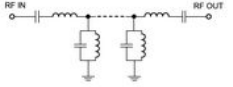
Bandpass Filter Electrical Specifications (T_{AMB}= 25°C)

CENTER FREQ. (MHz)	PASSBAND (MHz) (Loss < 3dB)	STOPBANDS (MHz) Loss > 20dB		Loss > 30dB		MAXIMUM DEVIATION FROM LINEAR PHASE (deg.)	VSWR (:1) Passband		Stopband
Fc	F1 - F2	F3	F4	F5	F6	Fc ± 30MHz	Typ.	Max.	Typ.
440	410 - 470	320	650	200	850 - 1500	±6	1.3	2.0	20

Typical Frequency Response



Functional Schematic



Core functions

Power amplifiers

Successfully validated @435MHz

SKY65377-21: 450 MHz Transmit/Receive Front-End Module

Applications
- Automated meter reading
- Advanced metering infrastructure
- ISM systems
- Range extender

Features
- Range extender
- Transmit output power > +30 dBm
- High-efficiency PA
- Analog power control
- Integrated control logic
- Internal RF match and bias circuits
- All RF ports internally DC blocked
- Shutdown mode
- Small footprint, MCM (28-pin, 6 x 6 mm) package (MSL3, 260 °C per JEDEC J-STD-020)

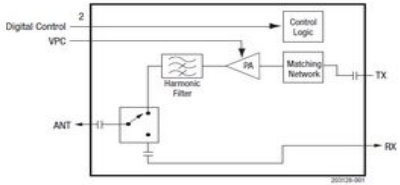


Figure 1. SKY65377-21 Block Diagram

Description

The SKY65377-21 is a high-performance, transmit/receive (T/R) front-end module (FEM). The device provides a complete T/R chain with T/R switches.

The device transmit chain features +30 dBm output power and a 40 percent Power Added Efficiency (PAE). The module also has a shutdown mode.

Successfully validated @145MHz

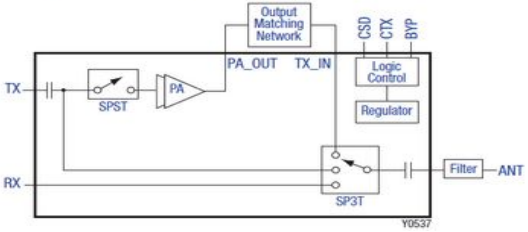
SKY65367-11: 169 to 170 MHz Transmit/Receive Front-End Module

Applications
- Automated meter reading
- Advanced metering infrastructure
- ISM systems

Features
- Transmit output power: >+30 dBm
- High efficiency PA
- Receive loss: < 0.4 dB
- Transmit bypass mode with 0.9 dB insertion loss
- Sleep mode current: < 1 µA
- Integrated control logic
- Small footprint MCM (16-pin, 4 x 4 mm) package (MSL3, 260 °C per JEDEC J-STD-020)

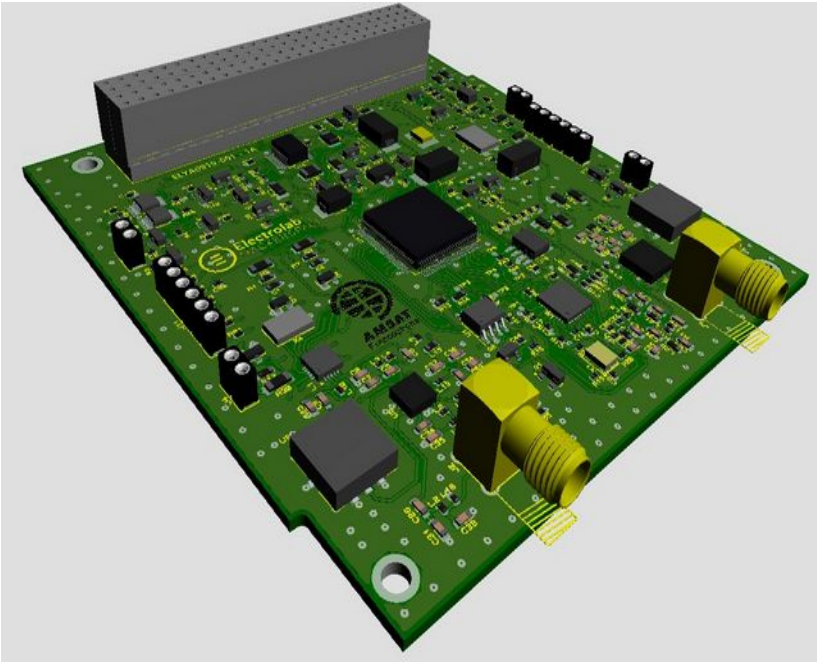
Description

The SKY65367-11 is a high-performance, transmit/receive (T/R) front-end module (FEM). The device includes a power amplifier (PA) capable of more than +30 dBm of transmit output power (V_{CC} = 3.6 V) at more than 43 percent PAE for the module (63 percent for the standalone PA). For current-sensitive applications, the PA can be bypassed to save battery current.



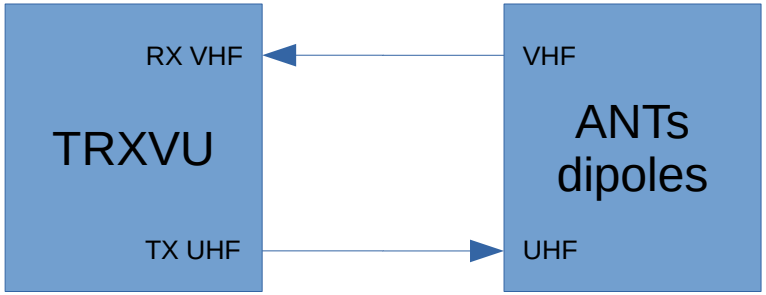
Core functions

Previews

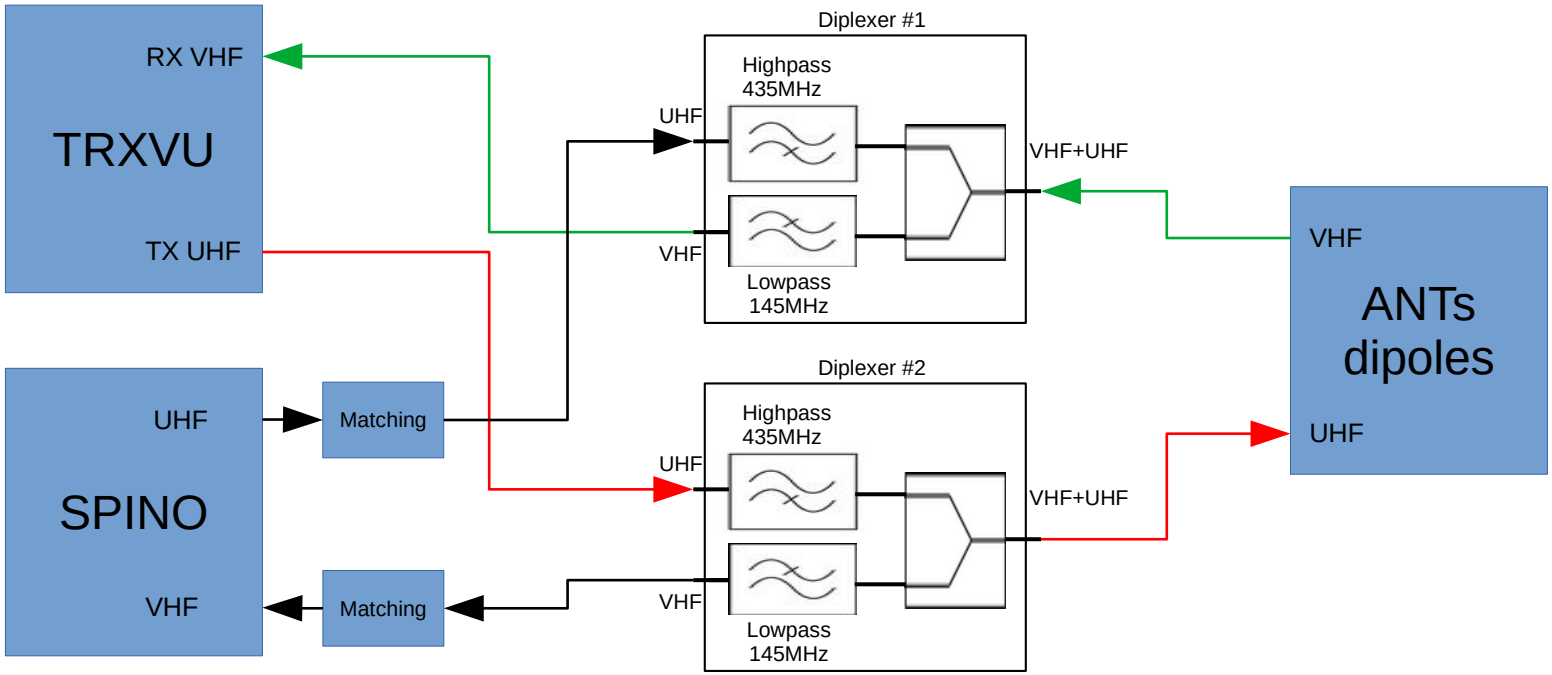


Antenna coupling

- **Amateur radio payload should be as transparent as possible to the radio system**



Antenna coupling

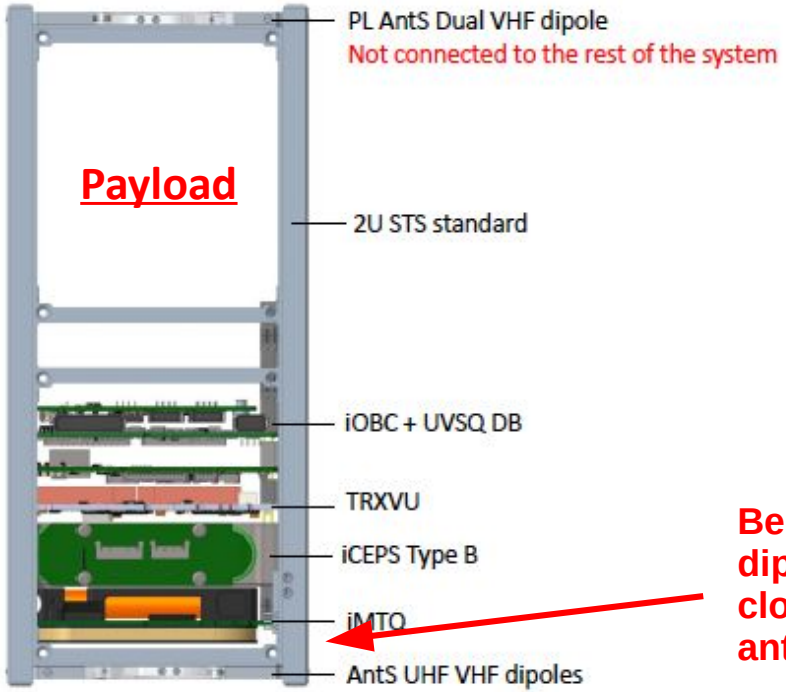


Antenna coupling

Antenna coupling :

- **Seen from TRXVU**
  - ✓ Diplexer loss : 0,3dB est.
  - ✓ VHF RX on a true VHF antenna, and UHF TX on a true UHF antenna...
- **Seen from SPINO**
  - ✓ VHF TX on an actual UHF-optimized dipole, and UHF RX on an actual VHF-optimized dipole
  - ✓ Non-optimized antenna + matching + diplexer loss : est. 2.5dB
  - ✓ Dual TX/RX non testable… SPINO will only work with VHT TX and UHF RX on this mission…
- **Diplexers on a new board...**

Inside the Cubesat



Best location for diplexer board : as close as possible to antennas...