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Rad-Hard: From LEO to Deep Space

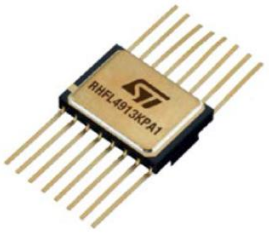
An update on ST's latest Rad-hard analog, digital and discrete semiconductor components and technologies, with focus on the ST LEO series of Rad-Hard in plastic package and the new Point of Load converter RHRPMPOL01

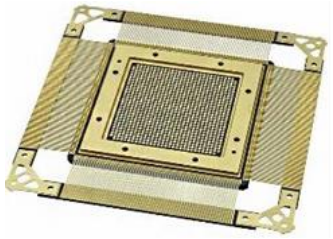
ST Developers' Conference 2021

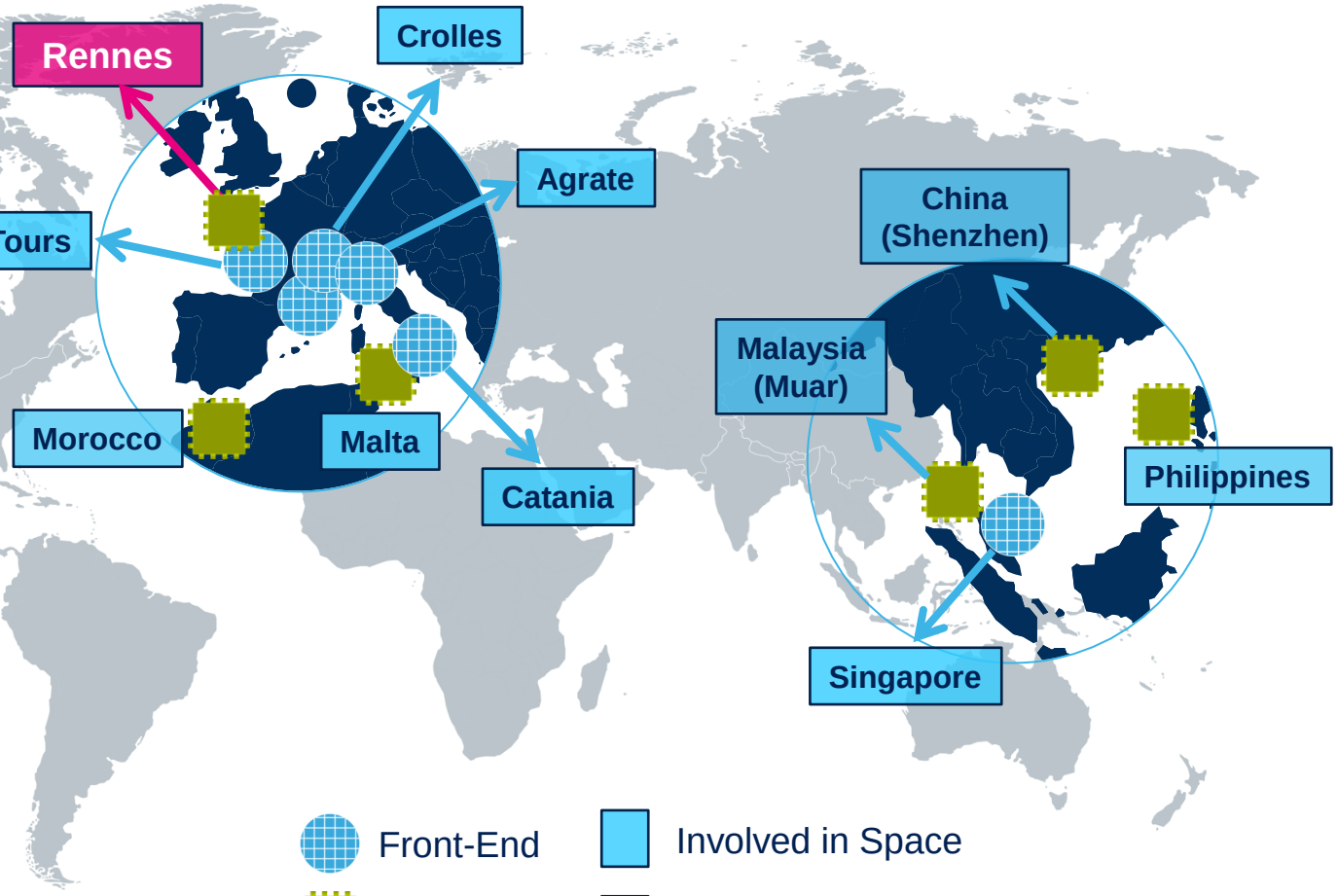
Piercarlo Scimonelli, Andrew Michel, Thibault BRUNET

State of the art integrated supply chain

BEM&T Space qualified plant in Rennes







40+ year commitment to Space

- State-of-the-art assembly facility
- QML-V, JANS and ESCC Certified
- Proprietary rad-capable technologies
- Millions of flying hours without failures

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A large Rad-Hard product offering

Fast expanding portfolio

Interfaces

LVDS fail safe series
16-bit bus interfaces
Level shifters

Logic

CMOS4000: 100 krad
HCMOS & HCTMOS: 50 krad
AC & ACT MOS: 300 krad

Bipolar & MOSFET transistors

ESCC 100 krad LDR bipolars
JANSR+ 100 krad LDR & VLDR bipolars
Cost effective rad-hard MOSFET

Schottky diodes & Rectifiers

JEDEC D5 compatible series
Power series up to 600 V / 40 A

ASIC technologies & platform

Space platforms:
BCD6s SOI 320nm up to 190V
65nm, 28 nm FDSOI

ST Rad-capable technologies:
CMOS - SiGe 130 & 55 nm
Imaging technologies – Integrated passive RF

Power management

Linear Voltage regulators
PWM controllers
Gate drivers
Integrated Current Limiter
Point of Load switching converter

Analog

Data converters
Operational Amplifiers and Comparators
Voltage reference

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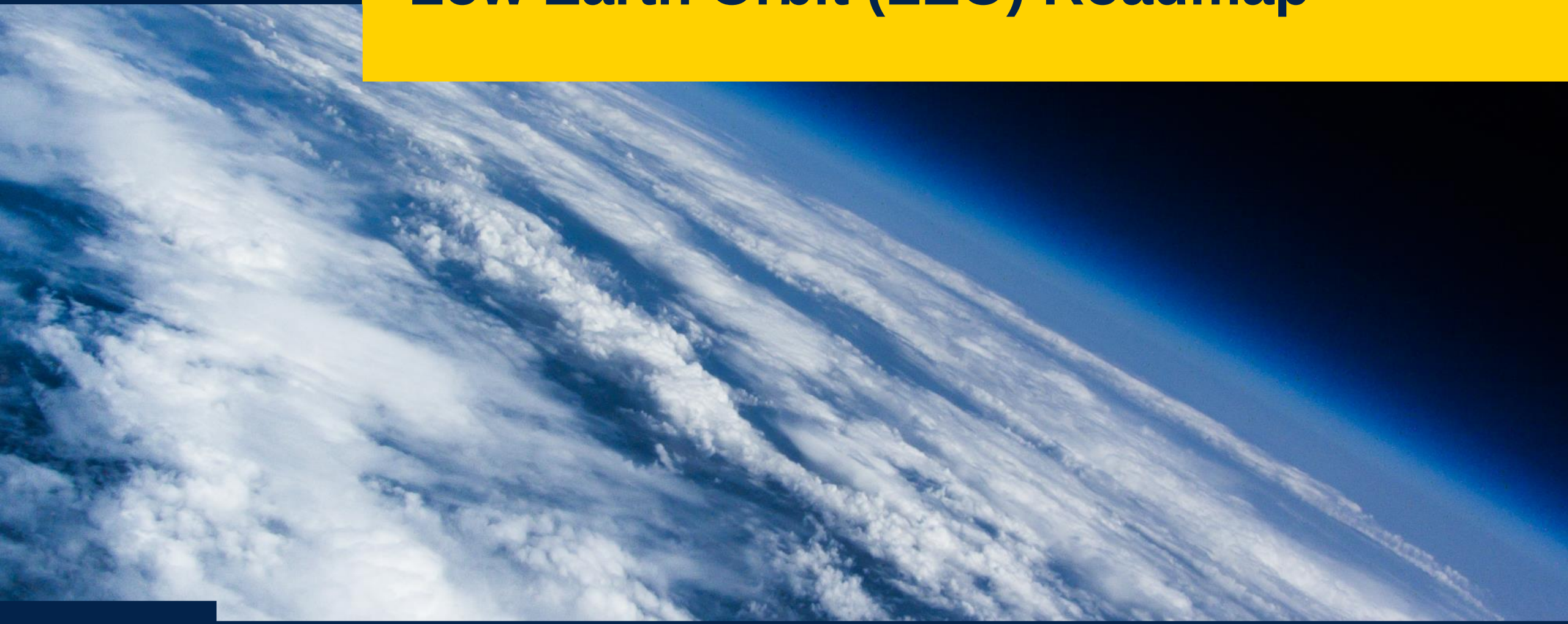
What’s new in ST Space offer

Diodes	STPS series of Rad-Hard Power Schottky from 45 to 150V, up to 80A	ESCC Qualified
Diodes	STTH series of Rad-Hard Power Rectifiers: 200 and 400V up to 80A	ESCC Qualified
Bipolar	2ST15300 High Voltage 300V NPN	ESCC Qualified
Logic	Grounded lid AC & VCX, RHFOSC04 oscillator & clock driver, RHFAHC00 150MHz	QML-V Qualified
D/A Converter	RHRDAC121: 20MHz 12-bit SAR	Eng. Models
A/D Converter	RHFAD128 8-channel 12-bit serial output ADC 1Msps	QML-V Qualified
Current limiter	RHRPMICL1A: Integrated configurable power switch with floating ground	QML-V Qualified
Point of Load	RHRPMPOL01: Fully featured 7A with current sharing and synchronization	QML-V Qualified
LEO series	LEOAD128, LEOAC00, LEOAC14, LEOAC244 and LEOLVDSRD	ST Qualified
Rad-Hard ASIC	65nm: ESCC qualified, 28nm: FD-SOI, Now Flying	Qualified

Low Earth Orbit (LEO) Roadmap



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The New Space sweet spot

Rad-Hard

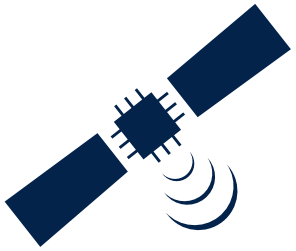
- Limited product portfolio
- Long Lifecycle
- Security of Supply
- Limited technology portfolio
- Low volume
- Ceramic Packages

NEW SPACE

SWaP-C

COTS

- Large product portfolio
- Short to medium Lifecycle
- Flexible supply chain
- New technologies
- High volume
- Plastic packages



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A solution to a new paradigm?

Requirements

Class 1 missions

Low quantity

15 year + lifetime

100 krad(Si) + 85 MeV.cm2/mg

Constellations

Higher quantity

5 to 10 years lifetime

20 to 50 krad(Si) + 40 to 60 MeV.cm2/mg

Solutions

Industry Preferred: agency qualified

- ✚ **Fully screened rad-hard ceramic hermetic**
- ✚ Known cost of ownership / lead time / risk
- ━ Limited product and performance offer

Alternative: COTS + Upscreen

- ✚ Upscreen up to the mission profile
- ━ Higher cost of ownership / lead time / risk
- ✚ Larger product and performance offer

Industry Preferred: plastic rad-hard

- ✚ **Plastic rad-hard with optimized screening**
- ✚ Known cost of ownership / lead time / risk
- ━ Limited product and performance offer

Alternative: COTS + upscreen

- ✚ Upscreen up to the mission profile
- ━ Higher cost of ownership / lead time / risk
- ✚ Larger product and performance offer

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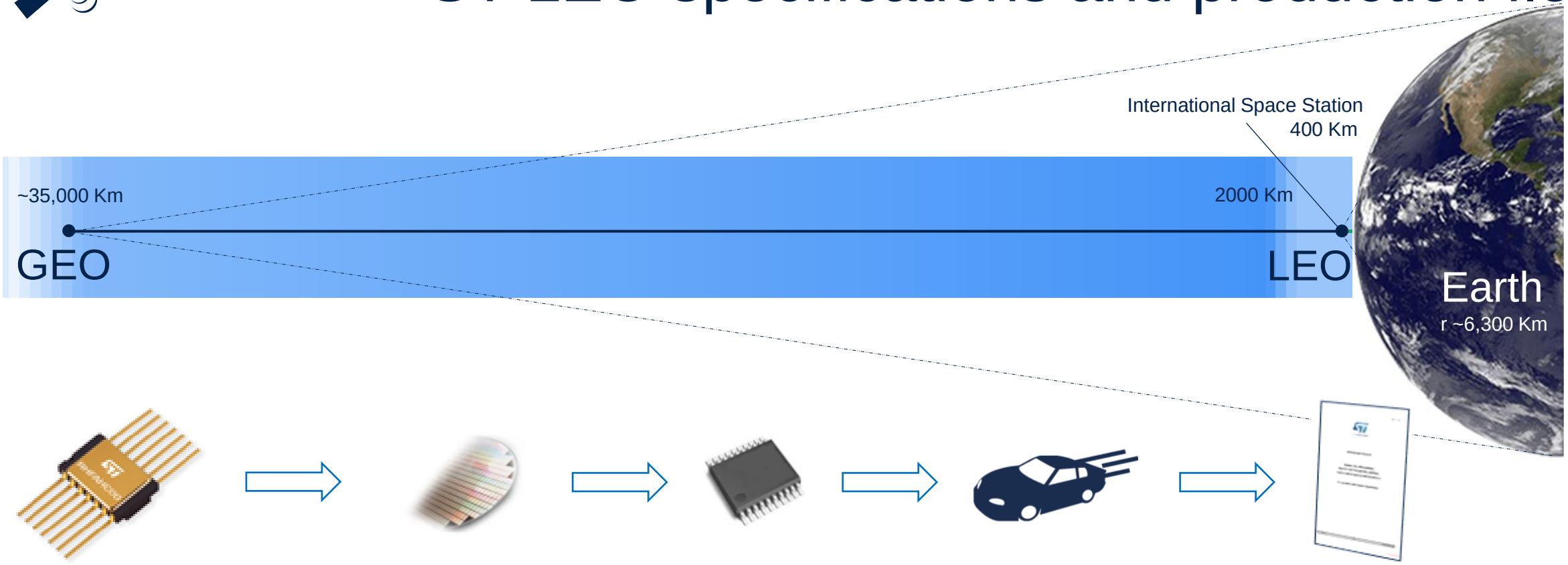
ST LEO specifications and production flow



Existing Rad-Hard material in Ceramic package
- 100/300krad(Si) TID
- 120MeV.cm²/mg
- QMLV, ESCC

Dice optimized for assembly in Plastic package

Rationalized to
- PSO20 (Power)
- TSSOP20 (Analog)

AECQ-100 production lines + Radiation tests

DM00695640
ST-LEO Spec
- 50krad(Si) TID
- 43MeV.cm²/mg
- No SLDC
- MOQ up to 1ku

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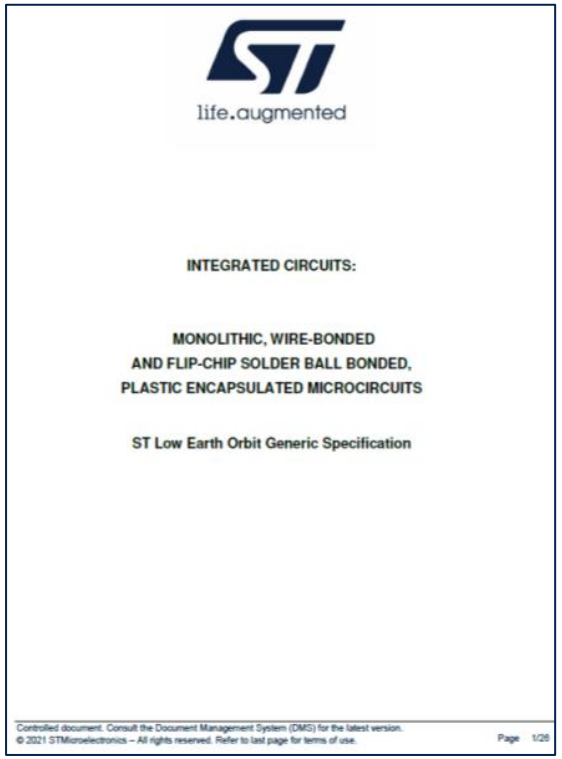
LEO series: Rad-Hard Plastic
AEC-Q100 based

Step	Description
Specification	TID 50krad(Si) – TNID when relevant @ 3.10^{11} proton / cm2 SEL free @ 43MeV.cm2/mg minimum + characterization up to 60 MeV.cm2/mg SET / SEU / SEFI… characterized up to 60 MeV.cm2/mg when relevant Operating temperature : -40°C to 125°C with 100% test at Low / Room / High temperature No serialization – No Burn in Certificate of Conformance
Die	Front end with ST Process control Electrical Wafer Sort with PAT(1), GPAT(2) and Percentage Defective Acceptance Wafer Lot Acceptance Test : HTOL + TID up to 50krad(Si)
Package	Assembly lines of AEC-Q100 qualified products Default finishing Ni/Pd/Au – Default wires : Gold Molding compound characterization (including RML(3) & CVCM(4)) Selected packages : TSSOP20 – PowerSO20; Others under evaluation
Screening	Based on AEC-Q100 : 10 Thermal cycles @ 100% + CSAM by sampling + external visual
Logistic	Packing : Tape & reel MOQ : 1000 pieces typical Max 2 date code per shipment & 1 date code / reel – No additional traceability at order entry Max date code : 5 year
Support	PCN & PTN Management : as ESCC / QML-V Customer services & technical support by ST Space team



ST LEO specifications now available

(1) Part Average Testing; (2) Geographical Part Average Testing
(3) Recovery Mass Loss : target : < 1% (4) Collected Volatile Condensable Material -Target : < 0.1%

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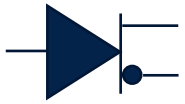
LEO series: On-going developments status

Logics



LVDS

ADC

Voltage regulators

CP	Function	Plastic Package	Sample	Flight Model	Part Number DM / FM
LEOAC00	Quad NAND	TSSOP20	Now	Now	LEOAC00PT-D LEOAC00PT
LEOAC08	Quad AND	TSSOP20	Now	4Q21	LEOAC08PT-D LEOAC08PT
LEOAC14	Hex Schmidt Inverter	TSSOP20	Now	Now	LEOAC10PT-D LEOAC14PT
LEOAC32	Quad OR	TSSOP20	Now	4Q21	LEOAC32PT-D LEOAC32PT
LEOAC74	DUAL Flip / Flop	TSSOP20	Now	4Q21	LEOAC74PT-D LEOAC74PT
LEOAC244	16-bit Transceiver	TSSOP20	Now	Now	LEOAC244PT-D LEOAC244PT
LEOLVDSRD	LVDS Transceiver	TSSOP20	Now	Now	LEOLVDSRDPT-D LEOLVDSRDPT
LEOAD128	8-channel 12-bit ADC	TSSOP20	Now	Now	LEOAD128PT-D LEOAD128PT
LEO3910	LDO	PSO20	Now	4Q21	LEO3910PDT-D LEO3910PDT
LEOPOL1	Switching POL	PSO36	4Q21	1Q22	LEOPOL1PDT-D LEOPOL1PDT

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News in Data Converters

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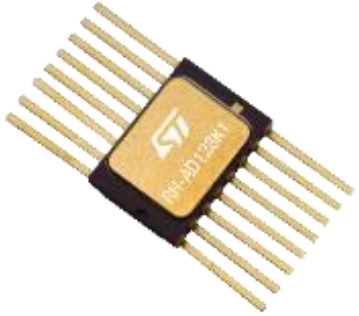
SMD : 5962F18204

RHFAD128

Rad-hard Industry standard 1 Msps 8-channel 12-bit ADC

KEY FEATURES

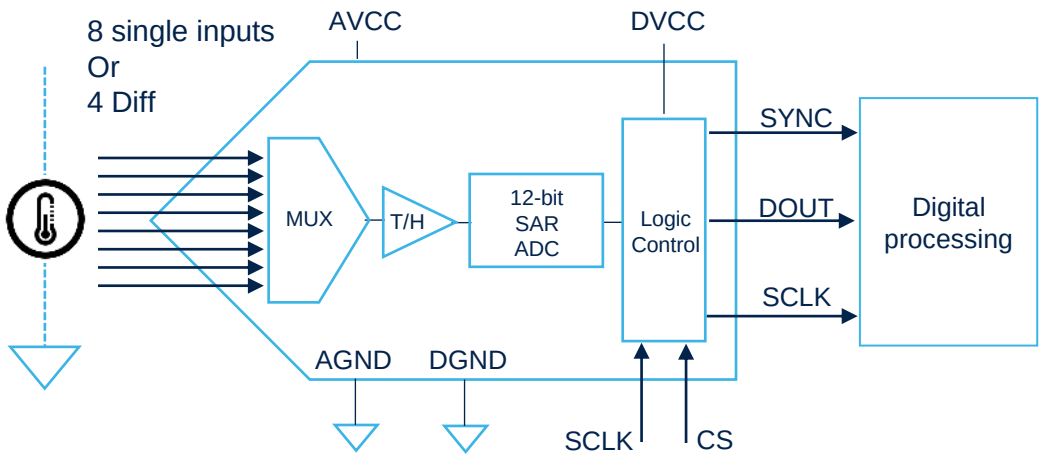
- Industry standard pinout
- No conversion glitch
- SAR architecture
- 12-bit, 50ksps to 1Msps sample rate
- 11.1 ENOB min. over -55/125C
- 4.5mW max @ 3.3V 1Msps, 3µW in shut-down
- 3.3V supply and I/Os
- 8-channel MUX, single-ended input
- 4-channel MUX, diff input
- SPI compatible



Flat-16
Metallic lid
internally grounded

RADIATION HARDENED

- RHA guaranteed at 300 krad(Si) – ELDRS free
- SEL-free up to 125 MeV.cm^2/mg @ 125° C
- SEU immune up to 32 MeV.cm^2/mg
- SEFI immune up to 62 MeV.cm^2/mg



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SMD: submitted

Engineering Models available

RHRDAC121

Rad-hard 20MHz low power SAR 12-bit DAC

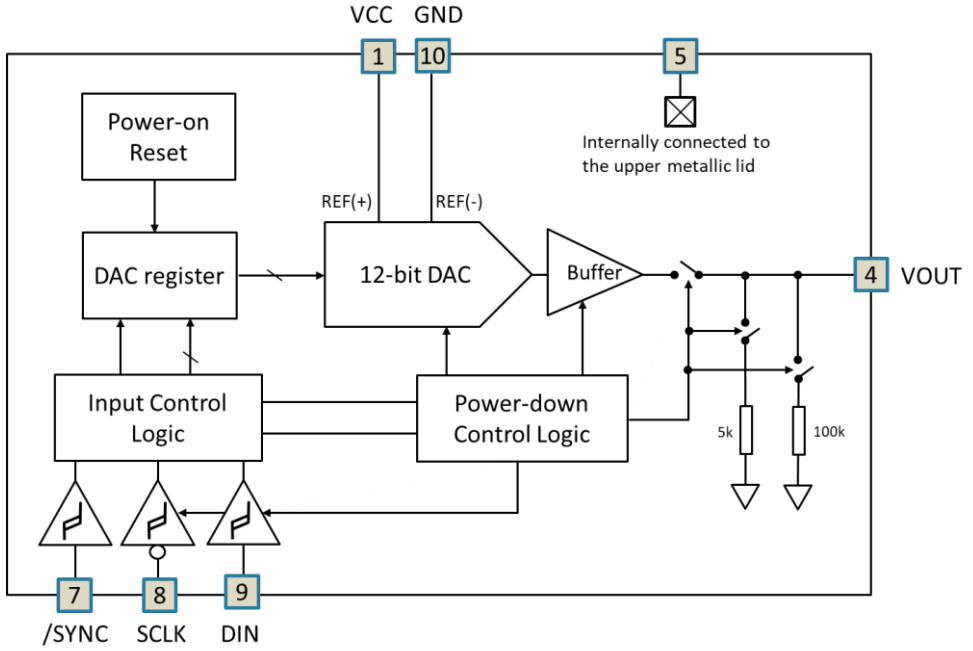
KEY FEATURES

- Industry standard pinout
- 4.8V AMR
- 2.3V to 3.6V Supply Range
- 12-bit SAR architecture
- 180uA consumption at 20MHz clock and Vcc max
- 10mV max offset error
- Rail-to-Rail Voltage Output
- Power-On Reset to Zero Volts Output
- Internal voltage reference
- Series input, SPI compatible
- SYNC Interrupt
- Power-Down Feature

RADIATION HARDENED

- RHA guaranteed at 100 krad(Si)
- SEL-free up to 120 MeV.cm^2/mg @ 125C
- SEE report available upon request

Flat-10
Metal lid
internally grounded



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News in Logics and Interfaces

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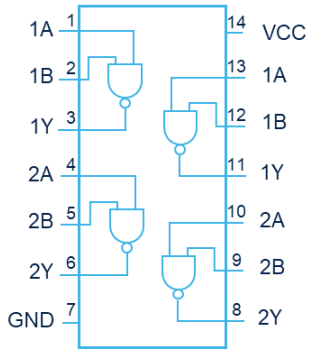
SMD: 5962F18202

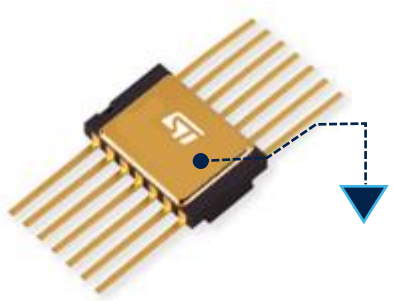
RHFAHC00

Rad-hard High speed NAND gate

KEY FEATURES

- 1.65V to 3.6V operating supply
- 4.8 V AMR
- Ultra low power
- 50µA quiescent current (no load)
- 165µW at 3.3V
- Very high speed
- propagation delay of 3 ns max.
- Functionally tested at 150MHz
- FLAT14 with grounded lid

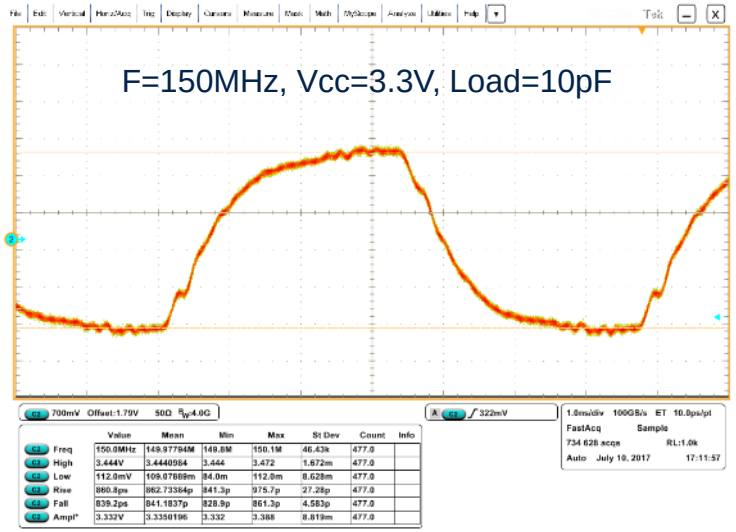




Grounded Lid:
AC/VCX Internal connection of the metallic lid to a pin for grounding

RADIATION HARDENED

- 300 krad (Si)
- SEL free up to 125 MeV.cm²/mg @ 125C
- SET free up to 62.5 MeV.cm²/mg @ 25C
- Proven CMOS 130nm technology



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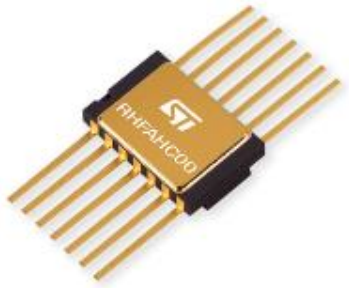
AC00 vs. AHC00



	5962F87549	5962F18202
	54AC00	RHFAHC00
Supply	**Nominal 2.5V 3.3V 5V Tested from 3 to 5.5V**	**Nominal 1.8V 2.5V 3.3V Tested from 1.65 to 3.6V**
Max Freq	**70MHz max (char)**	**+150MHz (char)**
Prop time	**9ns**	**3ns**
Output level @3V	VOH=2.9V for IOH=50uA	VOH=2.8V for IOH=100uA
Radiation	300 krad(Si) TID 110 MeV.cm2/mg SEL free 85 MeV.cm2/mg SET free	300 krad(Si) TID 125 MeV.cm2/mg SEL free 62.5 MeV.cm2/mg SET free
Tech	700nm	130nm
In production	yes	yes

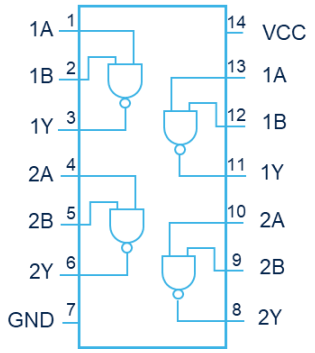
SMD: 5962F20207

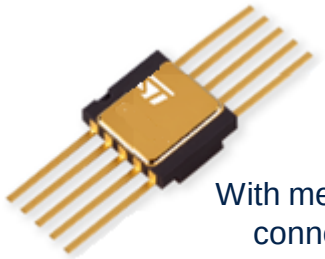
RHFOSC04

Rad-hard Crystal oscillator driver/divider

KEY FEATURES

- 1.8V 2.5V 3.3V logics compatible, 4.8V AMR
- 4 selected frequency-divided outputs
- 16MHz-120MHz Crystal range
- 18pF output capability
- -100dBc Phase-Noise at 170Hz@120MHz
- 3.4mA current consumption
- Enable/Disable with high-impedance output
- Dice: 1mm², 10-pads, 100x100µm
- Flat10 hermetic package
- HCMOS9A (130nm CMOS technology)





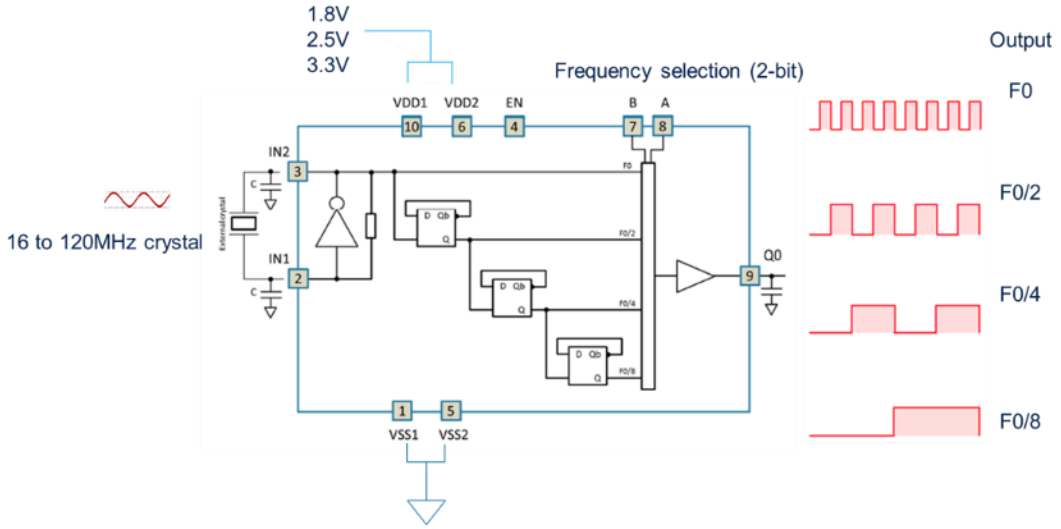
Flat-10

With metallic lid internally connected to ground

Die form

RADIATION HARDENED

- 300 Krad (Si)
- SEL free @ 120 MeV.cm²/mg @ 125C
- SET: Report available upon request
- Proven 130nm technology



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News in Power Management

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SMD : 5962R17211

RHRPMICL1A

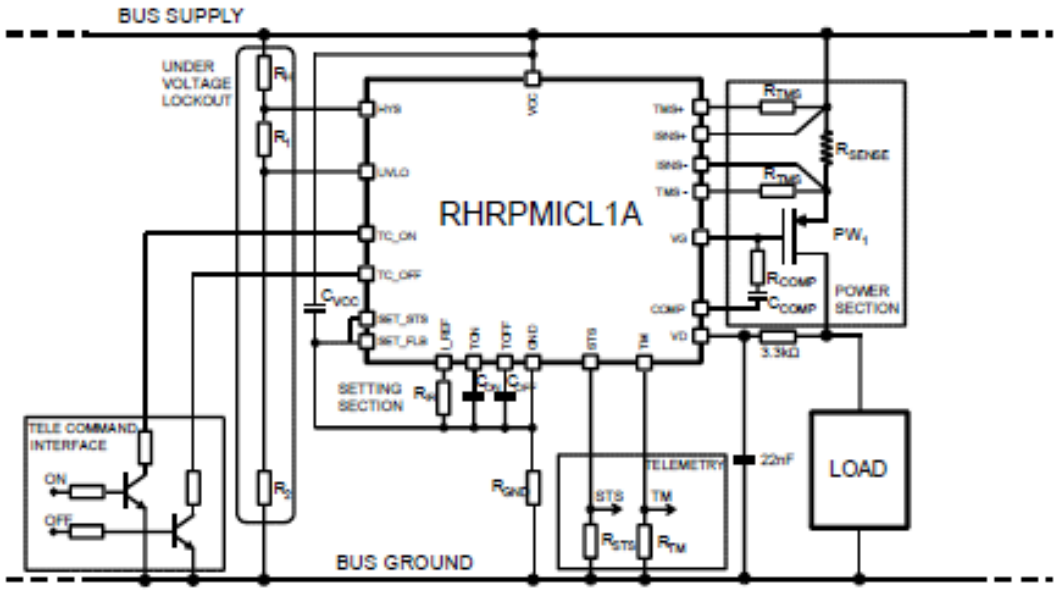
Rad-Hard Integrated Current Limiter

MAIN BENEFITS & FEATURES

- **Wide-range supply voltage: 8.5 – 52V DC**
- **Floating Ground functionality for >52V operation**
- Very Low DC current: typ 1.5 mA (2mA in Floating Ground)
- 3 Operation Modes
  - Re-Triggerable
  - Latched
  - Fold-back
- High Configurability
  - External current limit setting
  - Configurable trip-off and recovery times
  - Under-voltage thresholds (ON and hysteresis)
- Digital & Analog telemetries
- Flat-20 Hermetic Package

RADIATION HARDENED

- TID: 100 krad (Si) ELDRS free
- SEL & SEU free up to 125 MeV.cm²/mg
- SET characterized



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SMD: 5962R20208

RHRPMPOL01

Rad-Hard Point of Load 7A monolithic step-down regulator

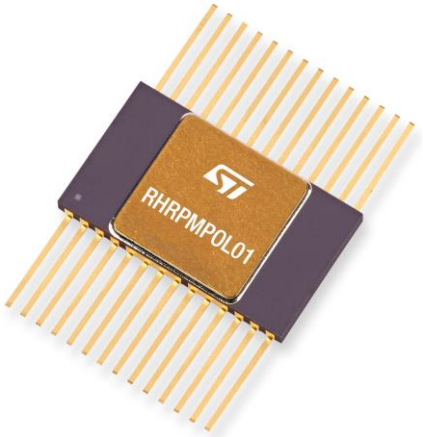
KEY FEATURES

- Input operating voltage range: 3.0V to 12V
- Output voltage range: 0.8V to 0.85xVin
- Fast load transient response Peak Current Mode control loop
- Integrated NCH MOSFETs for synchronous step-down conversion
- Integrated BOOT diode
- Fully protected:
  - Under & over voltage
  - Over temperature
  - 2 level over current protection
- Power good output
- Programmable switching frequency from 100kHz to 1MHz
- Easy smart out-of-phase synchronization of multiple devices(1)
- Current sharing configuration for higher load requirements
- Programmable soft-start

(1) No external components for 180° out of phase of 2 devices

RADIATION HARDNESS

- Total Ionizing Dose: 100 krad
- Tested ELDRS-free
- SEL-free up to 70 MeV/mg/cm2 **@ Vcc up to 7V**
- SEU-SEFI characterized up to Vcc 7V - Proton Free
- No performance degradation due to SET



Flat-28A

Die form

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SMD: 5962R20208

RHRPMPOL01
Application Tips

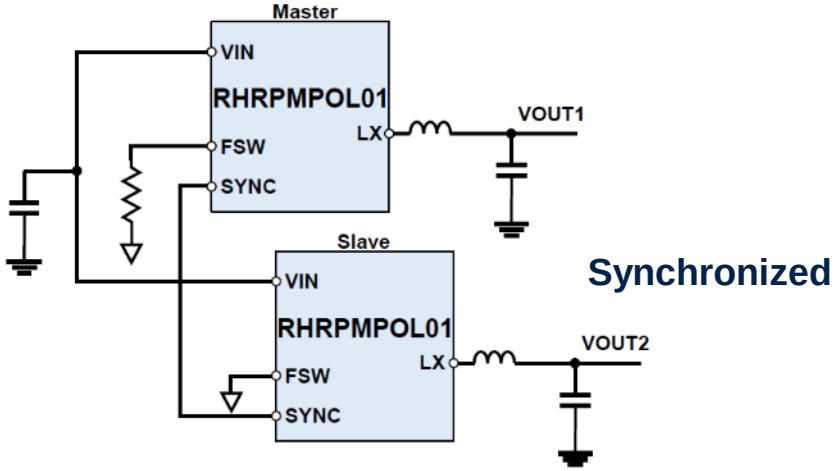
Synchronization for 180° out of phase dual output or Interleaving

Master mode
The device is automatically configured as Master **when pin FSW is > 0.15V**.
The pin SYNC, configured as output, provides a clock signal phase-shifted by 180º with respect to the internal clock signal.
It can be used to drive the pin SYNC of another RHRPMPOL01 configures as SLAVE

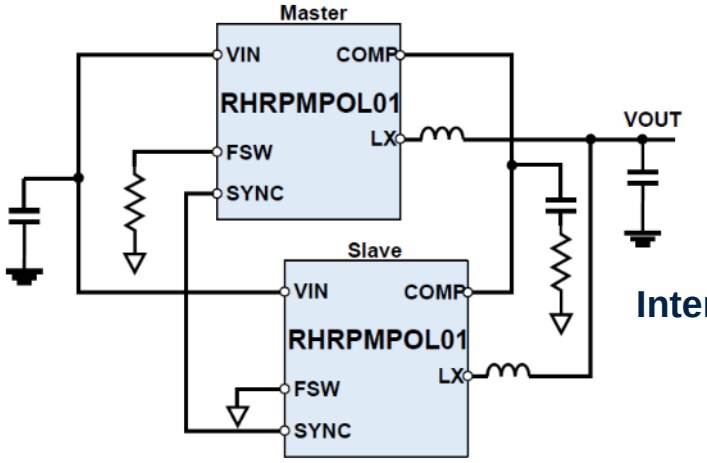
Slave mode
The device is configured as Slave **when pin FSW is forced < 0.1V**.
The SYNC pin, configured as input, accepts a clock signal which can come either from another RHRPMPOL01 configured as master or an external clock.
If an external clock is available, then two RHRPMPOL01 configured as Slave can work in parallel.

Interleaving & Current Sharing
Connecting two RHRPMPOL01s through the SYNC pin, they can synchronize each other with 180º phase shift switching interleaving, reducing RMS current absorption from the input filter and preventing beating frequency noise, therefore allowing a reduction in the size and cost of the input filter.

For **higher output current requirements**, two RHRPMPOL01s can be connected in current share configuration, and providing up to 14A.



Synchronized



Interleaving

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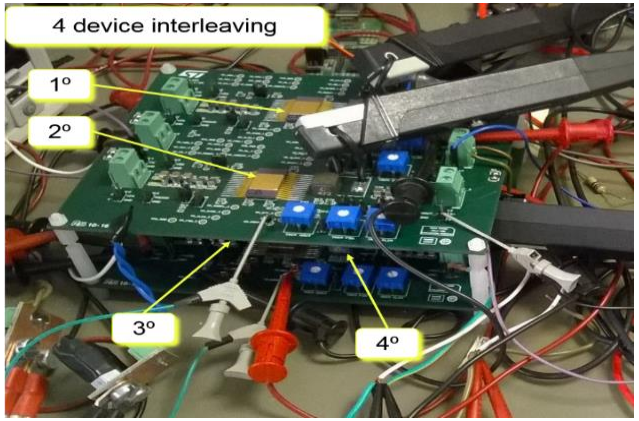
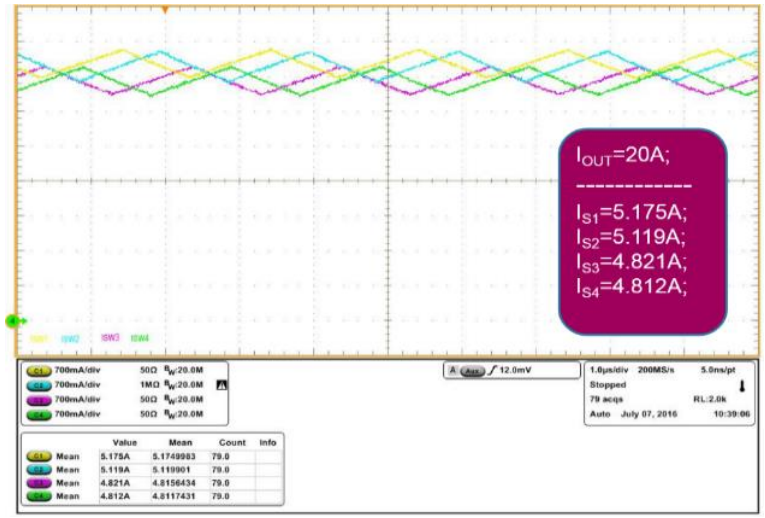
SMD: 5962R20208

RHRPMPOL01
Application Tips

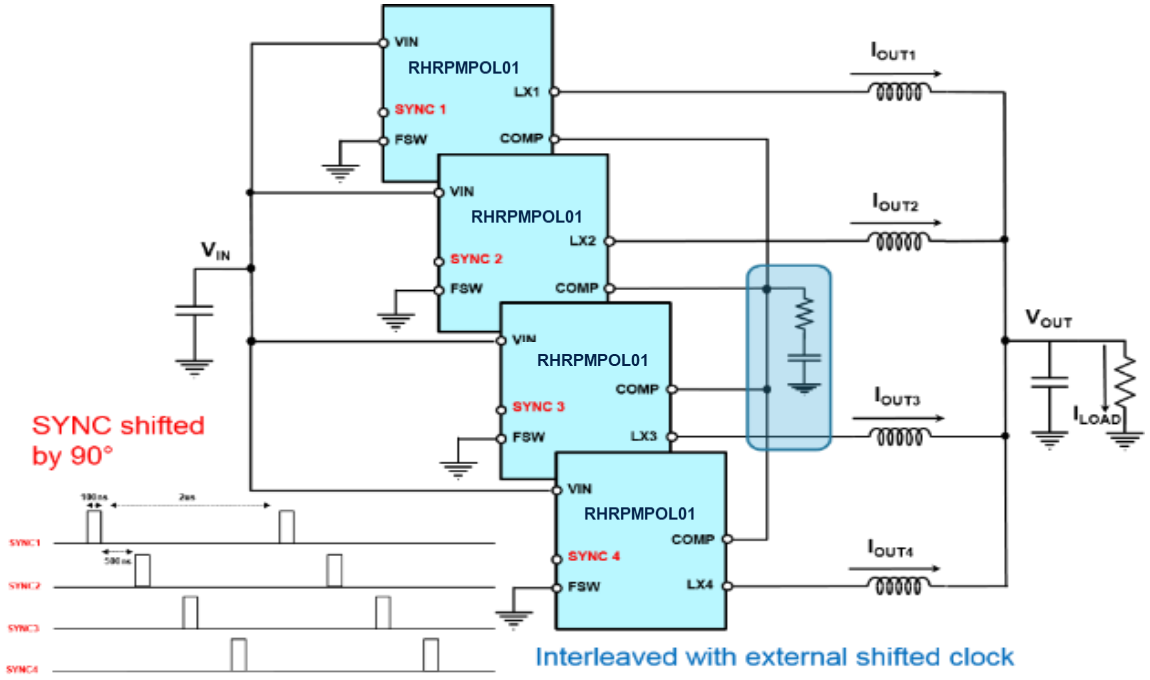
Interleaving 4 devices





Master and Slave (4 devices) single output:
To guarantee the right phase shifting **each device works as slave** and an external circuit provides the 90º phase shifted SYNC signal:

$$0.9 * \frac{I_{LOAD}}{4} < ICOIL_{(1,2,3,4)} < 1.1 * \frac{I_{LOAD}}{4}$$



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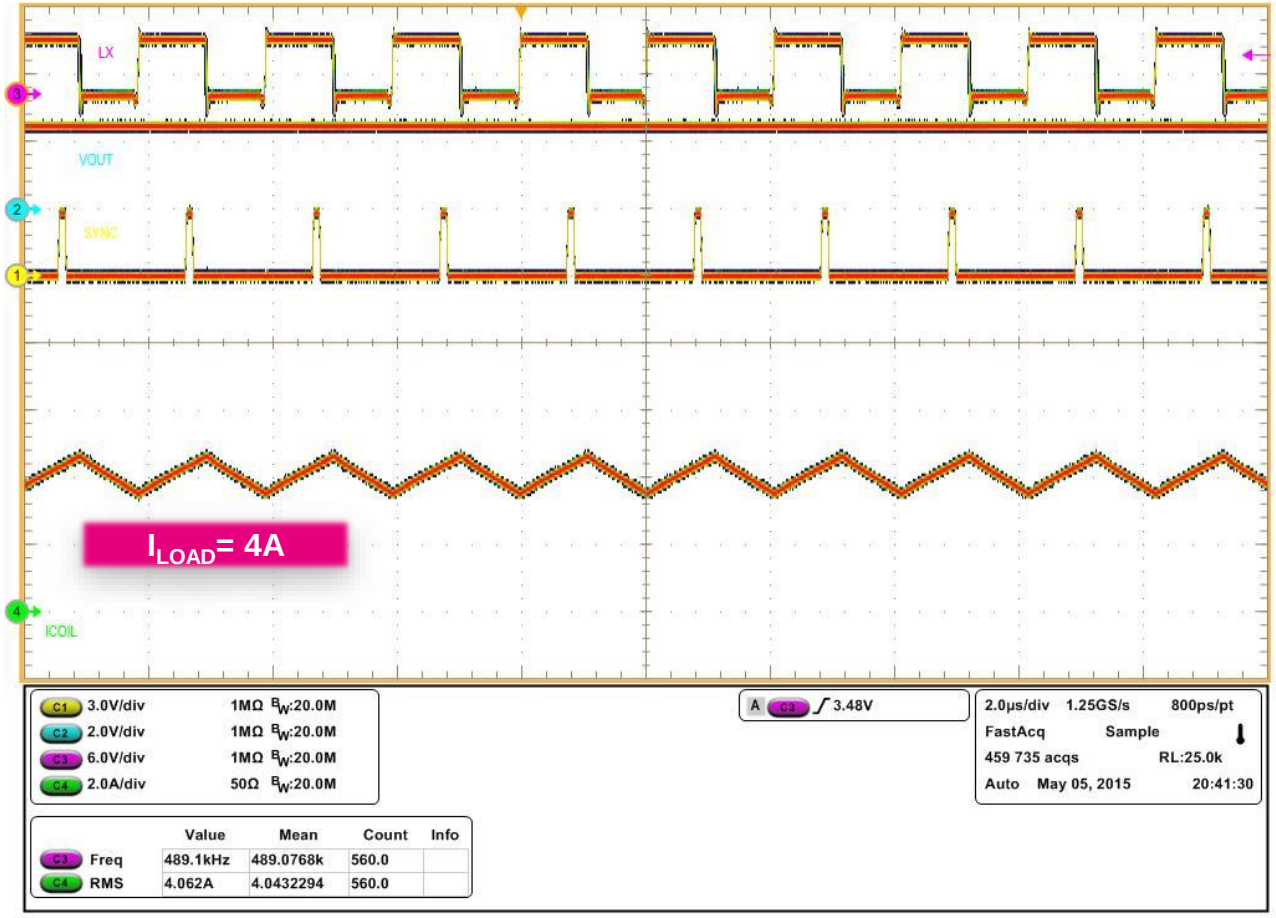
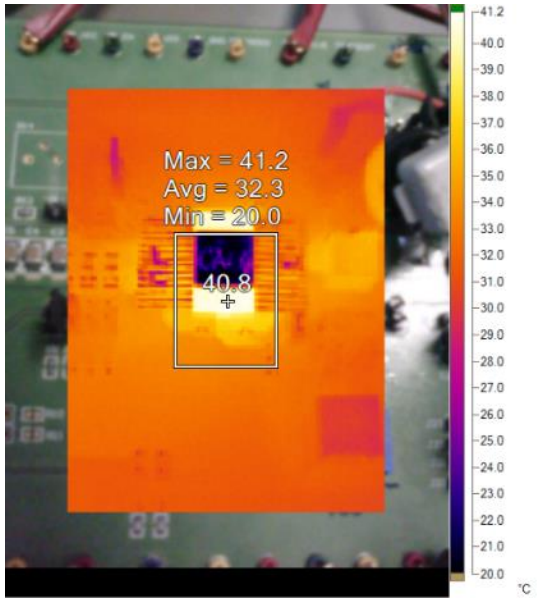
SMD: 5962R20208

RHRPMPOL01
Application Tips

Current Capability 1/3



- V_{IN} = 5V
- V_{OUT} = 2.5V
- COIL = 2.2µH
- FREQ = 500kHz
- I_{LOAD} = 4A
- EFF = 89%
- P_{DISS} = 1.27W
- Pack Temp = 41ºC



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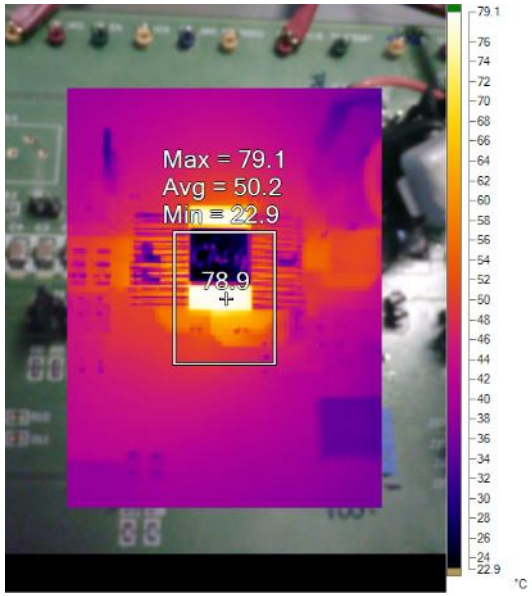
Current Capability 2/3

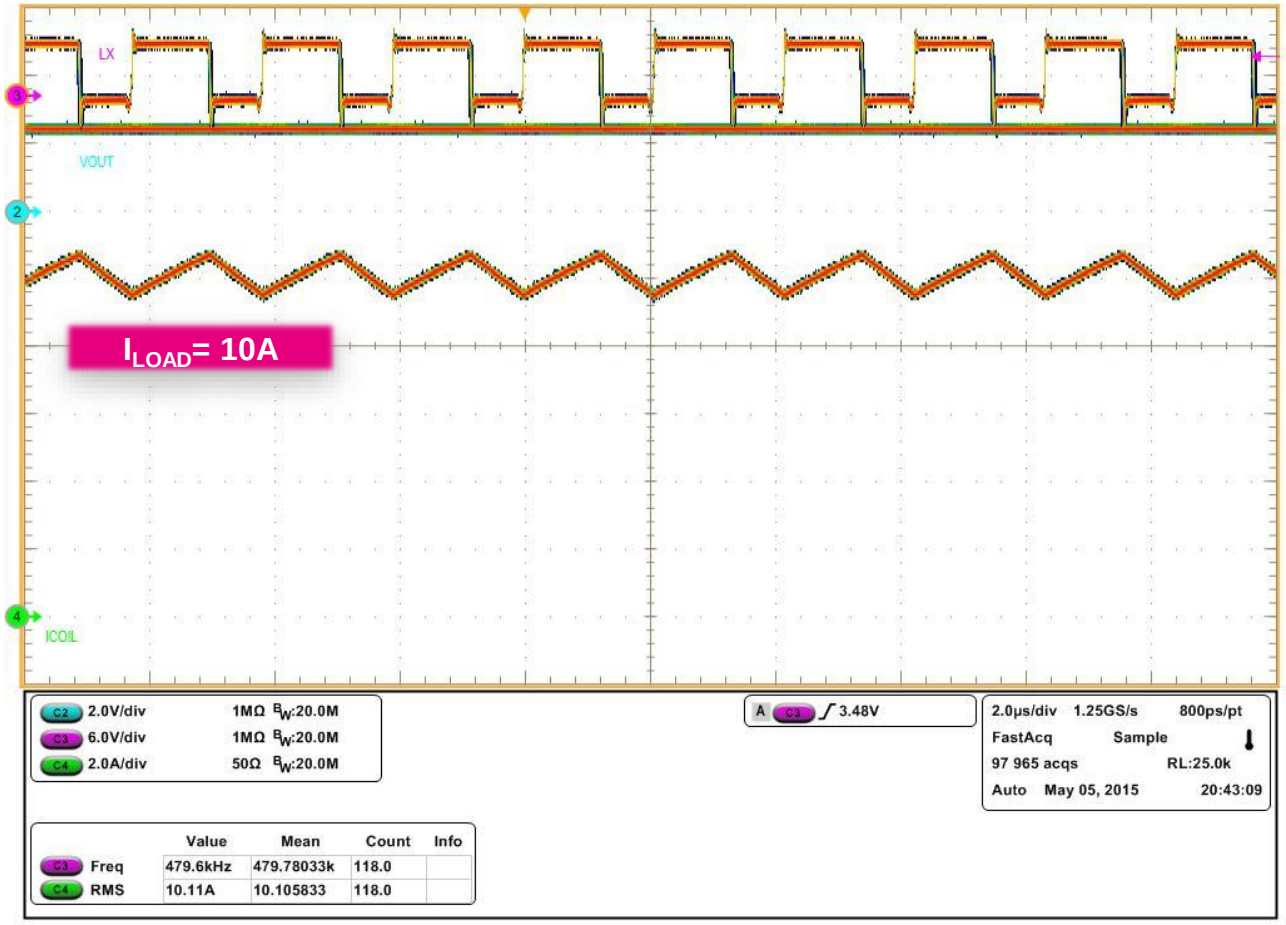
- V_{IN} = 5V
- V_{OUT} = 2.5V
- COIL = 2.2µH
- FREQ = 500kHz
- I_{LOAD} = 8A
- EFF = 83.2%
- P_{DISS} = 4.06W
- Pack Temp = 79ºC



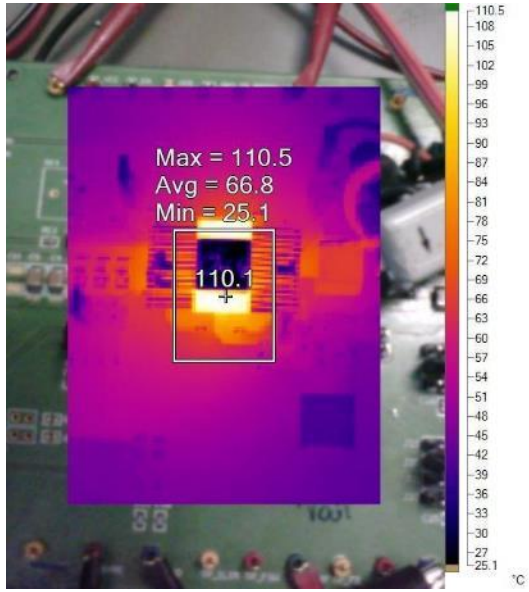
SMD: 5962R20208

RHRPMPOL01
Application Tips

Current Capability 3/3



- V_{IN} = 5V
- V_{OUT} = 2.5V
- COIL = 2.2µH
- FREQ = 500kHz
- I_{LOAD} = 10A
- EFF = 80%
- P_{DISS} = 6.32W
- Pack Temp = 110ºC



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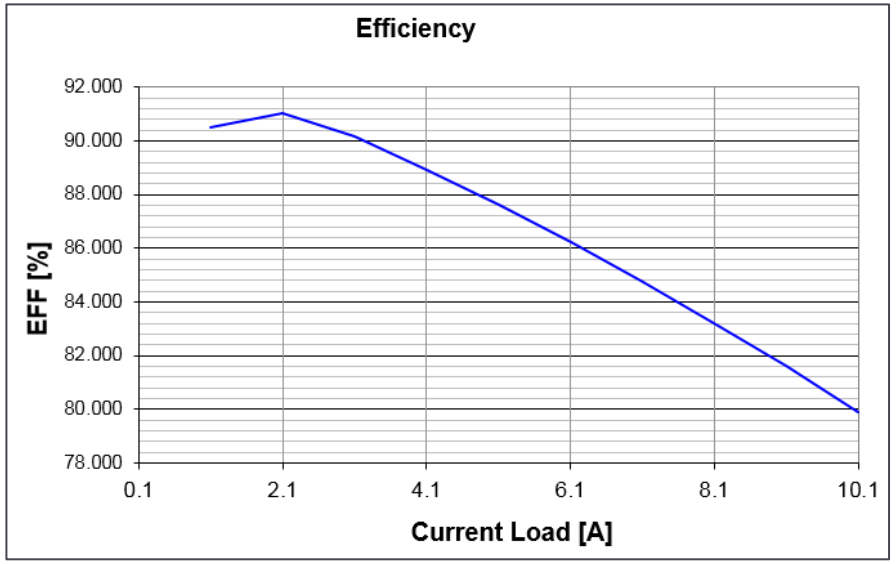
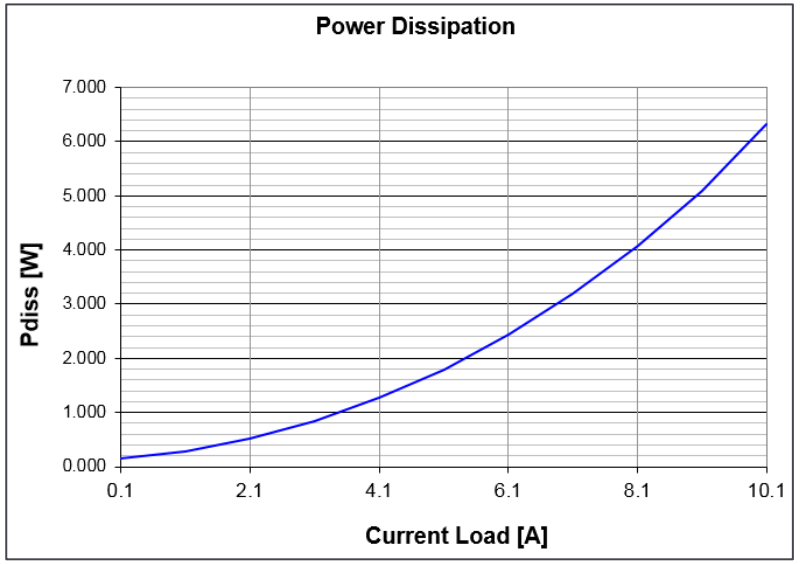
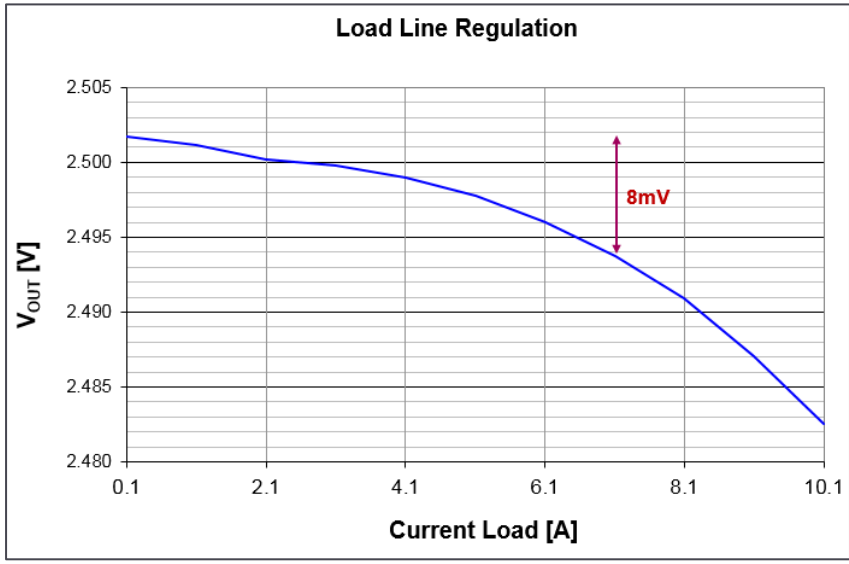
RHRPMPOL01
Application Tips

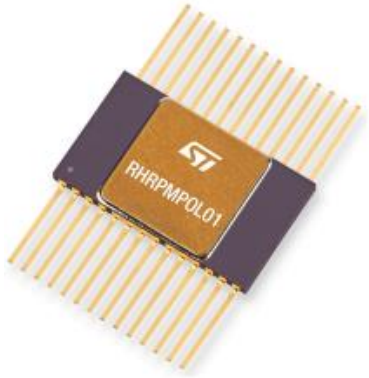
Efficiency, Power Dissipation & Load Regulation

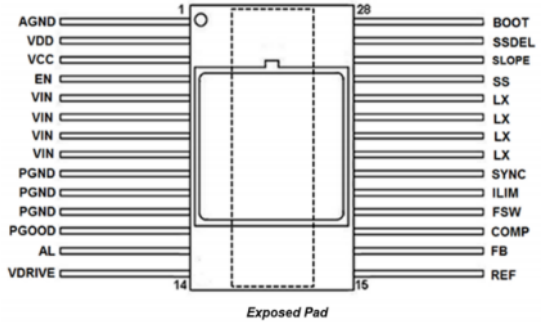






- V_{IN} = 5V
- V_{OUT} = 2. V
- COIL = 2.2µH
- FREQ = 50 kHz
- I_{LOAD} = 1A ÷10A





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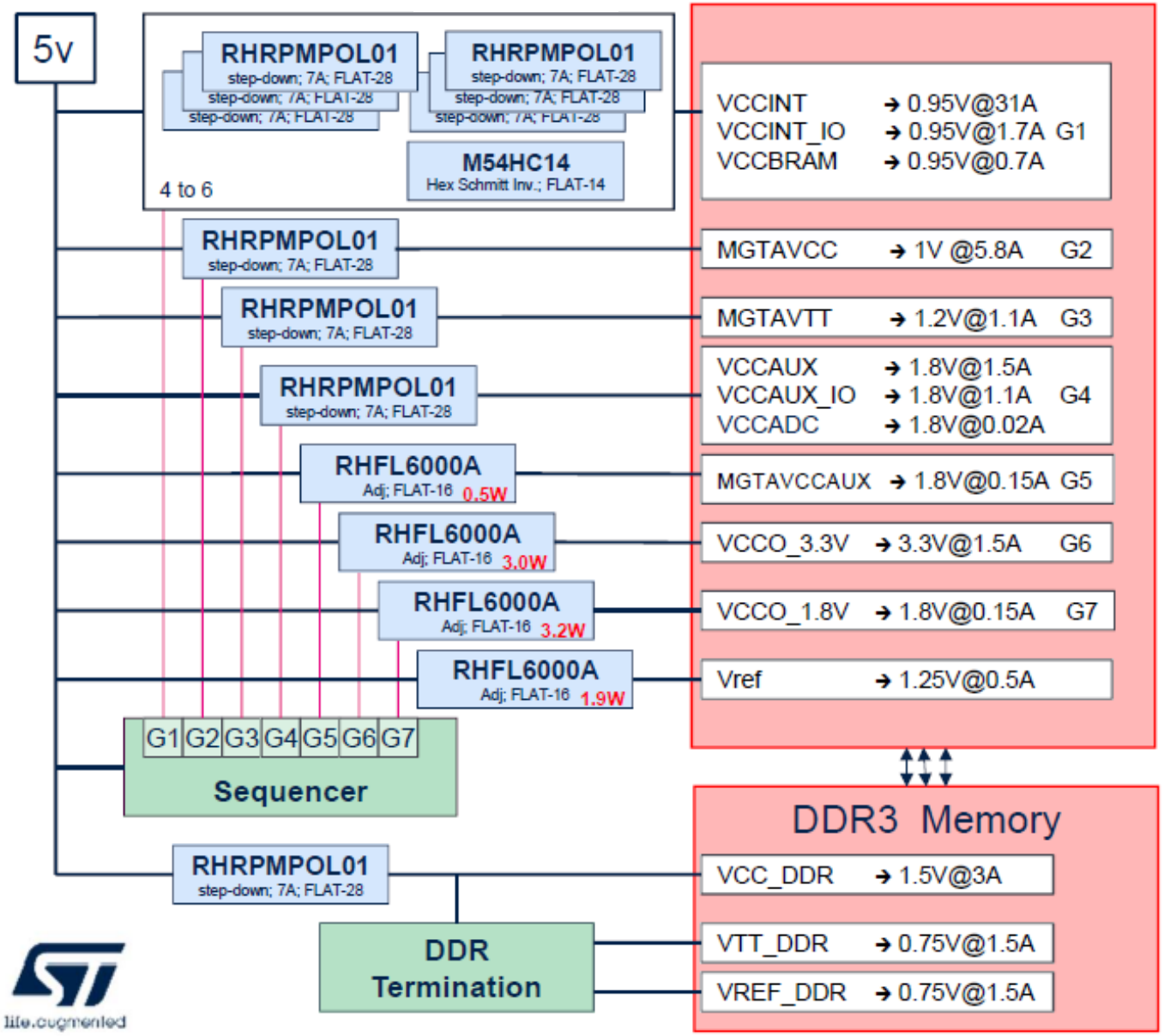
KU060 FPGA Power Reference Design



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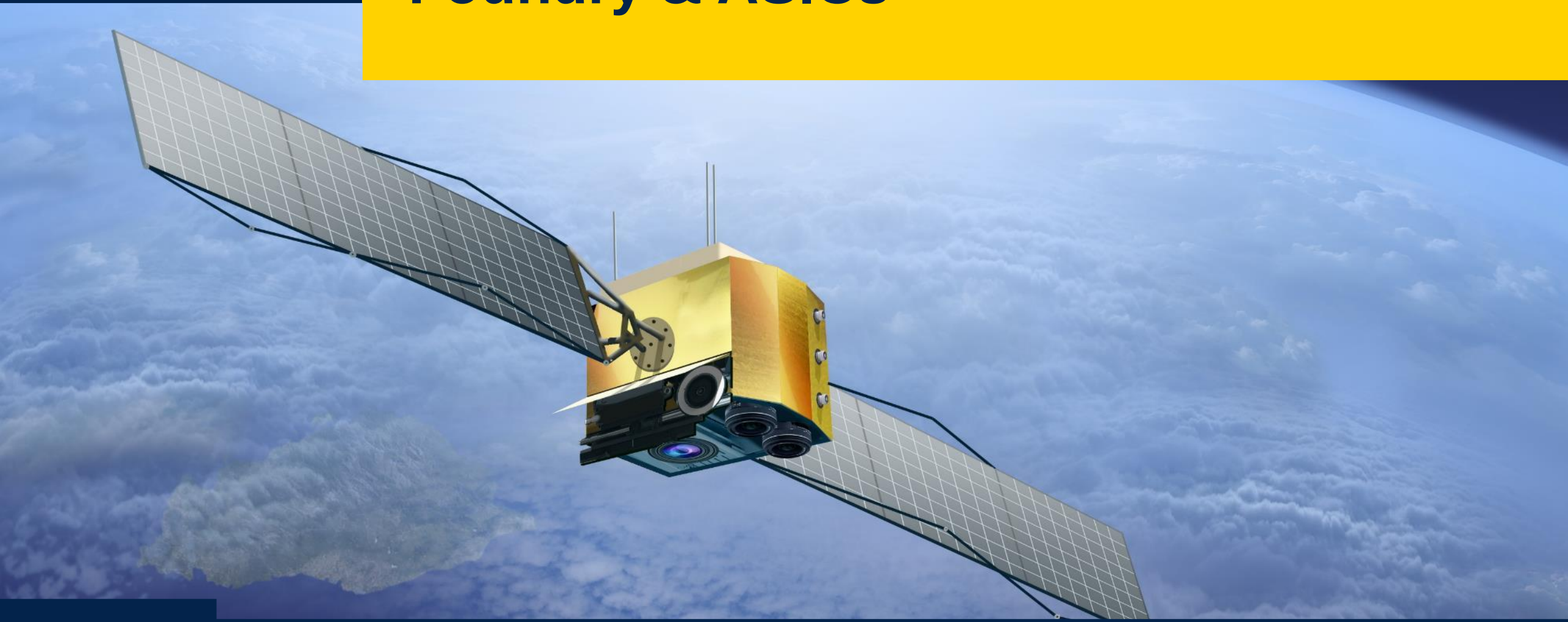
Foundry & ASICs



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High-End Space Foundry & ASICs

ST Integrated Solutions

Technologies for Space

28nm FDSOI: Flying
- 3 rad-Hard platforms - 5 mission profiles

Space 65nm: Development
- Rad-Hard platform - GEO mission profile

BiCMOS55: Development
- SiGe 55nm – FT 330 MHz
- Rad-capable

BiCMOS9: Flying
- SiGe 130nm – FT 220 MHz
- Rad-capable

BCD6s SOI: Flying
- 320nm Up to 190 volt
- Basic Rad-Hard library & IPs

Hardening Expertise

30+ years experience
- 1000s rad tests on many cells & chips
- Several technologies down to 7nm

Proprietary Tools & Methods
- Radiation sensors
- TID-aware aging models
- Multi-scale fault injection simulator
- SEU Montecarlo code
- Ultra-selective hardening (CPU, SOC)

Rad-Hard IPs & Libraries(1)
- SERDES, ADC, DAC, PLL…
- ARM : A53, R52 rad-hard macrocells

Integrated Supply Chain

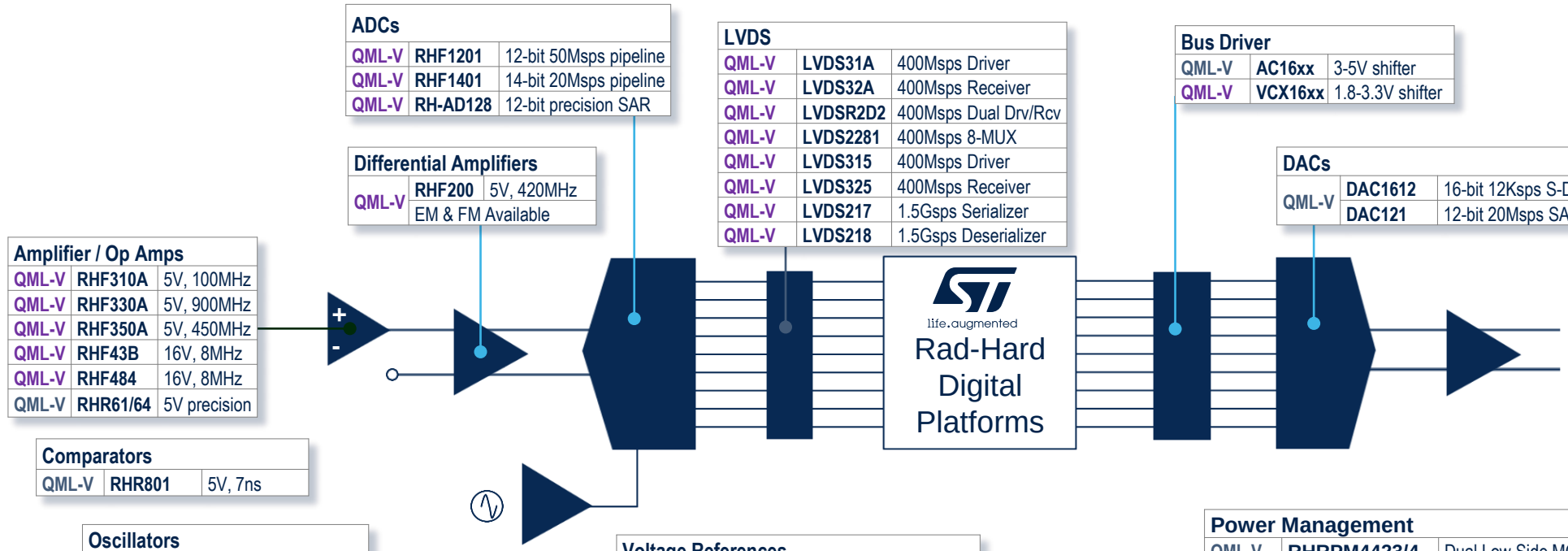
QML-V RHA - ESCC - JANSR

Upgraded Space BEM&T Plant

Large Package Offer
- Ceramic wire-bonded up to 625 pins
- Ceramic flip-chip up to CCGA-1752
- Plastic for Space
- Flip-chip organic substrate

(1) Deployed for Space in 65 nm and 28 nm FDSOI

QML-V and ESCC
Reference blocks



ADCs		
QML-V	RHF1201	12-bit 50Msps pipeline
QML-V	RHF1401	14-bit 20Msps pipeline
QML-V	RH-AD128	12-bit precision SAR

Differential Amplifiers		
QML-V	RHF200	5V, 420MHz
	EM & FM Available	

LVDS		
QML-V	LVDS31A	400Msps Driver
QML-V	LVDS32A	400Msps Receiver
QML-V	LVDSR2D2	400Msps Dual Drv/Rcv
QML-V	LVDS2281	400Msps 8-MUX
QML-V	LVDS315	400Msps Driver
QML-V	LVDS325	400Msps Receiver
QML-V	LVDS217	1.5Gsps Serializer
QML-V	LVDS218	1.5Gsps Deserializer

Bus Driver		
QML-V	AC16xx	3-5V shifter
QML-V	VCX16xx	1.8-3.3V shifter

DACs		
QML-V	DAC1612	16-bit 12Ksps S-D
	DAC121	12-bit 20Msps SAR

Amplifier / Op Amps		
QML-V	RHF310A	5V, 100MHz
QML-V	RHF330A	5V, 900MHz
QML-V	RHF350A	5V, 450MHz
QML-V	RHF43B	16V, 8MHz
QML-V	RHF484	16V, 8MHz
QML-V	RHR61/64	5V precision

Comparators		
QML-V	RHR801	5V, 7ns

Oscillators		
QML-V	RH-OSC04	3.3V, 150MHz
QML-V	RHFAHC00	Quad Nand

Voltage References		
QML-V	RHF1009A	Adjust 2.5-5.5V 5ppm/°C
QML-V	RHF100	Fixed 1.2V, 5ppm/°C

Power Management		
QML-V	RHRPM4423/4	Dual Low Side MOSFET Drivers
QML-V	RHFL4913	2/3A Positive LDO regulator
QML-V	RHFL6000A	2A Positive LDO regulator
QML-V	RHFL7913	2/3A Negative LDO regulator
ESCC	ST1843/ST1845	Current-mode PWM Controllers
QML-V	RHRPMICL1A	Integrated Current Limiter
QML-V	RHRPMPOL01	7A Point of Load

Power Discrete		
ESCC/ ESCC	MOSFET	N & P channel, up to 100V
ESCC	Bipolar Transistors	NPN & PNP, 40 to 600 V
ESCC	Power Rectifiers	200 to 400 V
ESCC	Power Schottky	40 to 150 V
ESCC	Switching diodes	1N664x, 1N5806, 1N5811

Logics		
QML-V	AC/ACT	5V Advanced Logic
ESCC & Class-S	HCC	20V CMOS 4000
ESCC	HC/HCT	20V Logic

300krad 100krad 50krad

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Takeaways

- 5 LEO Rad-hard plastic products are ST qualified
- New RHRDAC121 Rad-Hard industry standard 12-bit DAC available
- New 7A Point of Load switcher RHRPMPOL now available
- ST opens its portfolio of rad-capable technology and state of the art supply chain for Space ASICs and ASSPs
- Stable lead times

Our technology starts with You

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