Advances in Space Qualified Flexible Rad-Hard Analog Microcircuits

JAXA MEWS 26, Oct 24-25 2013
MSK designs and manufactures high performance Hi-Rel and true Rad-Hard analog, mixed signal and power microcircuits.

LM’s A2100 and Boeing 720 bus use MSK custom hybrids and standard Voltage regulators

Aircraft and UAV’s use MSK’s precision Hi Rel Motor-Controllers and LDOs

Orbital Sciences Corp. 3rd Stage TVA uses MSK Motor Controllers
Select Programs using MSK …

- WGS
- GPS III
- A2100
- ACeS
- Iridium
- SBIRS
- AEHF
- GOES-R
- Solar Probe
- ISS
- Alphasat
- Galileo
- Bepicolombo
- Solar Orbiter
- Hayabusa 2
- E-Rosita
- Meteosat
- Exomars
- Loutch-M
- Express AM6
- ISS
- Dubaisat 2
- Musis
- Egyptiansat
- Radarsat (CA)
Product overview

**MSK is a leading manufacturer of hybrid microcircuits for the Aerospace and Defense industry**

- Radiation hardened IC’s, hybrids and modules
- Voltage regulators
- Motor controls
- Power modules up to 1700V / 1200A
- Amplifiers
- RF modules
- Custom hybrids
MSK facilities and certifications

Company Information:
• Located in Liverpool, NY, USA
• Business: 60% space, 30% MIL, 10% commercial aerospace

43,000 sq. ft. area, 16,500 sq. ft. state-of-the-art clean room
• Class II (10,000 particle per cu ft) general manufacturing area
• Class I (100 particle per cu ft.) laminar flow area for pre-seal inspection

MSK Quality
• Class & K screening and qualification to MIL-PRF-38534
• Class V certification to MIL-PRF-38535 approved
• Calibration to ANSI compliant Z540-3
• Certification to AS9100 awarded February 2006

Customer Quality Communication:
• Space Data-Pack can be delivered with every shipment
• Special testing performed upon request
• Non compliance is traced and communicated
• Product change/material obsolescence is communicated to direct customers and representatives
• MSK regularly accepts visitors to tour our facility and audit our systems after some arrangement and formalities
The following slides detail Q&R Controls documented in our Space Data-Pack. Courtesy of Q&R Manager Dan Miller, head of JEDEC chapter 13.4
Includes wirebond and hermetic seal process controls

- Both are adequate although companies add value to both for improved process control

**Wirebond controls**

- Requirement: In-line group B - destruct wire testing on each machine every 13 weeks
- MSK performs this weekly to validate the machines and operators
- MSK Performs 300C bake with destruct bond pull and ball shear
- MSK performs destruct bond pull testing and ball shear testing prior to wirebonding of flight devices using simulated devices
- No current JEDEC plans to change wirebond process controls

**Hermetic Seal controls**

- MSK’s hermetic seal process is in accordance with MIL-PRF-38534
- Some companies perform Internal Vapor Analysis process monitoring
Class K screening has not changed in many years although JEDEC is discussing tighter leak test limits

- MSK believes the science behind the air exchange of a hermetic device could allow oxygen or other gases inside a device and could potentially cause a device failure.
- A potential but unlikely failure is present in all manufacturing processes and materials and it is up to Industry to reduce risk in high reliability electronics.
- MSK supports tightening of the fine leak limits.
- MSK is reviewing different leak test methods available and will be making a capital investment within the next 3 months. The new test method include:
  - Kr85 leak testing
  - Optical leak testing
  - CHLD leak testing
- MSK records helium fine leak data for each device
MIL-PRF-38534 Class K Screening

Typical Screening Options flowed down:

• Some customers require special testing of devices at pre-cap inspection to validate the device prior to continuing the processing.
  – These include SEM, destruct bond pull, die shear, etc.
  – MSK does not believe these tests are needed based on SEM at element evaluation, wirebond set up data is in compliance and processes are QML qualified

• Pre-cap photographs
• Full temperature testing with recorded data before to burn-in.
• Burn in test conditions being discussed in JEDEC
• Delta testing
• X-Ray in additional axis (X and Y modes)
Qualification testing to MIL-PRF-38534

A device must be qualified (QML compliant) once in the device's life unless a major change has been made.

- The initial compliant testing include:
  - Class K screening 100%
  - Final electrical/”Group A” electrical testing
  - In-line or End of line “Group B” testing
  - QML or “Group C” testing (if processes and materials are QML compliant, then Periodic Inspection testing should be performed)
  - Life test of the design at “Group C2”
  - “Group D” testing (normally package EE data is used for “Gp D”)

- For each Class K production build, as a minimum, the devices are
  - Class K screened
  - Final electrical/Group A tested
  - In-line or End of line Group B tested

- The QML and life test data performed initially does not have to be performed on future production builds.

Does MIL-PRF-38534 lack reliability testing for each build?
Main Themes Today – in Analog RH

High qualification cost, Low quantities, chip obsolescence and new knowledge of radiation environments drive us to…:

1. QML certified Hi-Rel microcircuits and processes to reduce time, risk and cost of qualification and purchase/ownership. More true for research missions where quantities are very small.

2. Flexible components and satellite systems, e.g. Programmable Satellite with FPGA’s, one Voltage regulator for many applications.

3. Supply Chain Aspects: Serve customers more effectively with focused dedicated reps/distributors and processes
1) Implementing a broad product range

Focusing the strengths of two industry leaders to bring new broadly usable products to the Space Market

“RH Dice Inside™”

- Leading edge analog circuit design
- Focused on widely used analog functions
- Extremely robust, rad hard wafer process
- Strong analog and power circuit design
- Leading edge, Hi-Rel micro-circuit packaging specialist
- Focused quality compliance to MIL-PRF-38534/5 Class K/V

>70 total part numbers
>30 SMDs
2) Flexible products, Rad Hard product selection guide

<table>
<thead>
<tr>
<th>Part Type</th>
<th>RH DICE Inside™</th>
<th>Description</th>
<th>SCD or SMD# Reference</th>
<th>Typical QRBW (MHz)</th>
<th>Max Vout @ 25°C (V)</th>
<th>Max Inc @ 25°C (mA)</th>
<th>Package Style</th>
<th>Status</th>
<th>TID rad(Si)</th>
<th>ELDRS rad(Si)</th>
<th>SEE - megarad(Si)</th>
<th>Neutron dose</th>
<th>SPICE model</th>
<th>WOCA</th>
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<tbody>
<tr>
<td>MSK100R1H</td>
<td>RH100R1HCE</td>
<td>Universal Class C Op Amp (3A peak output)</td>
<td>562R1122801</td>
<td>0.1</td>
<td>3.5</td>
<td>100</td>
<td>MPP-20</td>
<td>P</td>
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<tr>
<td>MSK101R1H</td>
<td>RH101R1HCE</td>
<td>Current sigma Amplifier (1µa, 10V, 200K)</td>
<td>RH117KDICE</td>
<td>0.1</td>
<td>1.0</td>
<td>500</td>
<td>FR-10</td>
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<td>RH150R1HCE</td>
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Available at www.ms kennedy.com
Proven 3-Terminal Regulators with much heritage

Solution to obsolescence: Work with space focused companies with stable support, systems and strong non-obsolescence policy.

- RH117/LM117 based MSK5972 5962R0921301K_X +1.5 Amp
- RH137/LM137 based MSK5973 5962R0921401K_X -1.5 Amp
- RH1086/LM1086 based MSK5970 5962R0921101K_X +1.5 Amp
- RH1085/LM1085 based MSK5971 5962R0921201K_X +3 Amp
- RH1185/LM1185 based MSK5940 5962R11230 – 3Amp
- RH1085/RH1185 based MSK5930..39 dual 5962-11229) +-3Amp
- RH117/137 based dual MSK5911…5914 Regulators +-1.5A

Wide Vin/Vout, Proven 100-300kRAD hard versions of competing up-screened LM117, 137, LM1085, 1086, 1185 VR’s.

QML Listed, Typical noise 0.003% * Vo. Used for VCO’s, RF and analog load. Noise is often poorly specified, customers need to test thoroughly

TO-257

SMD-1
3 PAD
CERAMIC

TO-254-8
MSK5800 Series Proven Rad-Hard VLDO’s for FPGA’s

• 3 - 7V input
• Adjustable Vo, or fixed 1% accurate
• Less than 0.45V dropout
• 300 kRad TID, 100kRad LDR
• SEE Tested
• Very popular for low to medium power FPGAs, replaces the MSK5900 proven by NASA/GSFC
• New Miniaturized MSK5805KRH 1Amp VLDO

0.55x0.49” 48% less 0.825x0.625”
Flexible new 1 Amp rad hard LDO architecture

MSK5976, 5977, 5978 and MSK5953 LDO’s demonstrate performance and application versatility and flexibility

Wide $V_{in}$: 1.5 - 40V, Can add R-drop to reduce losses

Separate bias pin for low $V_{in} - V_o$ dropout

“0” $T_c$ current source instead of reference = stable gain/phase independent of $V_o$

“Voltage Follower” Single resistor programmable output

Output = $V_{set}$ => output noise = noise on $V_{set}$ with Gain= 1, lower than other regulators

Low $V_{ce(on)}$ BJT = 30 - 500mV dropout from $V_{in}$

$V_o$ equals inverting input – can be as low as zero! Good for low voltage FPGAs

Fast transient response keeps digital load supplies stable
Flexible: It’s a building block, not just an LDO

Current Source

Paralleling with good current sharing

Two Terminal Current Source

Ramp Generator

Most Requests come as “I need a part like…” or “I need a quote for MSK59xx”, but discussions with creative designers, EEE component engineers and supplier application engineers reveal so much more potential than a simple LDO.
New 1 Amp LDO basic information

- 300 kRad TID, >60kRad ELDRS
- ELDRS rugged RH bipolar design
- Wide $V_{in} / V_{out}$ range
- SEL/SEU free, small SET’s at up to 87MeV*cm2/mg

**MSK5976**
Isolated TO-257, 3-pin

**MSK5977**
Tab is output, split bias
DLA certification in progress

**MSK5978VRH**
Single regulator
Class V screened
DLA certification in progress

**MSK5953KRH**
Dual regulator
thermally enhanced
QCI in progress
Flexible 4A Step-Down Regulator – MSK5059

- Wide 4.3 - 16V $V_{\text{in}}$
- Fixed 500kHz $f_{\text{sw}}$ for easy filtering
- Sync-pin up to 1 MHz helps control noise
- Enable pin
- 0.25 – 35mA quiescent current for good efficiency at low current
- Fast current mode architecture = fast transient response, easy compensation, stability, small solution
- External compensation / EA output allows flexible output filter choices
- Frequency / Current foldback over current protection, fault tolerant
- Rugged rad hard bipolar design with 150-500mV $V_{\text{ce(on)}}$, 70 mΩ
- Over temp and overload protected
- $V_o = 1.21V$ min 4.5A $I_{\text{pk}}$ limit
- Precision 1.21$V_{\text{fb}}$ for low $V_o$

New available!
Solid Specs and design tools for Switching Regulator

- 100 KRad TID, 50 KRad ELDRS
- SEE >160MeV*cm²/mg tested for SET/SEL
- Robust rad hard low cost bipolar design
- Multiple packages to meet needs such as cooling
- Evaluation boards support design with varying parameters
- MSK5032 = Non Rad Hard version

**New, available!**

**MSK5044RH** (5962R11231)
Isolated case

**MSK5048RH** (5962R11232)
Case = GND
With sync pin

**MSK5052RH**
C_in, C_o HF filter, sync, external
V_c included

**MSK5059RH**
16-pin flatpak, single chip
Available as 5962R11234

SMD available soon
MSK5055/5063 7-65V, 0.01-15A Step down Regulator

- Vin 7-65V, Vo 1.23-36V
- Fsw 100-500kHz
- Sync up to 600kHz
- MSK5063RH includes special MOSFETs
- Very low 130uA standby current
- Very high efficiency at low currents 75-85%
- Advanced design for protection, noise control

**Status:**
- EM available
- MIL-PRF-38534 class K QCI pending
- 300KRAD TID, LDR report due Jan 2014
- Elements SEL/SEU/SEGR tested, report pending

**New, available!**
Wide Input High Side Current Sense Amplifier

- Use sRH6105 – Rad hard version of unidirectional LT6105 in tiny flatpack-10, or Quad in FP-16
- Accurate: 1% accurate gain, 300µV Vos
- 2.85 - 36V supply
- 0- 44V input independent of supply
- MSK196RH = Single
- MSK496RH = 4 Channel
- MSK6000RH: 2 Channel + High Side Switch

Applications:
- Power management distribution units (PMDUs)
- Board mounted current monitoring of power supplies and loads on digital boards

Status:
- TID 100Krad – Report available
- 50 kRad ELDERS due Dec – Jan 2014
- Passed QCI, QML-K certification to follow

New product!

TYPICAL APPLICATION CKT

Applications:

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MSK6000 Evaluation board
4. Supply Chain Aspects

Sales force & Distribution
ITAR Processes
Addressing the world
Using a dedicated sales force

*Timely and accurate Communication of market specific technical information is crucial:*

Reputable local sales force – Distributors focused on Space

- knows or happily learns what we are talking about, what QCI, MIL-PRF-38534 is, Group A, B, C tests etc.
- Proper handling and adhering to Export Control Regulations is easier, less ITAR fear
- No distraction when Apple or Nokia calls 😊
- Does not need re-training with every PO.
- Does not faint at the sight of a $10,000 price for an “IC”, or a 30 week lead time, or a 50 page Quality report etc.
MSK focus: Majority World Industry, so…

- Rad-Hard IC’s are export controlled under ITAR (“designed for spacecraft” Limits use of our product to Spacecraft not for/through China, Iran etc.
- Export control Reform initiated by the US Government proposed a new ITAR Regulation removing Rad-Hard Microcircuits from ITAR….
- …into new EAR Category 9A-515
- Japan should require no export license under “Exception STA”, conditions apply.

Until then MSK achieves:
- 100% approval rate for Japan, Europe, India, Taiwan, Dubai, Egypt etc.
- DSP-5 Export Licenses within 1-4 weeks BEFORE receiving P.O. from customers.
Cost effectively address a broad user base

1. **Geography:** Focusing on diverse and scattered customers

2. **Evolving industries:** Small quantities, education in all discussed aspects, very long time for program success.

3. “**Small customers**” Institutes with R&D projects like Solar Orbiter, Lunar Resurs can be considered good customers
   - All standardization aspects mentioned may help product acceptance
   - A manufacturer’s focus on the space industry and efficient set-up is needed: Support…or disappoint painfully
   - Efficiency in addressing RFT’s and RFQ’s is a must, to not disappoint a broad but tightly knit base of engineers and customers
Summary

*We addressed principles of Qualification Cost, Low Quantities, Obsolescence of Chips and space market economies of scale (if there is such thing)*

- Flexible QML certified components improve sustainability and reduce cost of ownership, delivery and hassle especially for high-performance small quantity missions.
- Forming partnerships between focused chip suppliers, focused QML certified manufacturers, and researchers can reduce cost, time and headaches and improve results.
- Partnering with dedicated field sales and distributors to support and service users and avoid disappointing customers…or industries
- A focused manufacturer for the world space market has “luxuries” of educating markets in product, procurement, export control etc. Other suppliers may be distracted or won’t afford, flip-flop in and out of a market.
NPM High Technologies Co.,Ltd.
Contact: Naohiro Yago , email: N-Yago@npm-ht.co.jp
TEL:+81-3-3813-8847  FAX:+81-3-3813-8836
2-16-13,Hongo,Bunkyo-ku,Tokyo , 113-0033

Please contact for all MSK business including:

• MSK factory visit, audit, and tour

• Requests for Quotation or technical information for:
  – Products and evaluation boards
  – QML information and space data-package
  – MIL-PRF-38534 and MIL-PRF-38535 Lot testing such as DPA, Life-, Vibration-, shock-, and Radiation- tests
  – Special Evaluation boards and support for Single Event testing
Thank you!
Steve Dokopoulos
MS Kennedy
s.dokopoulos@mskennedy.com

Questions?