New DC/DC Converter for Space Applications

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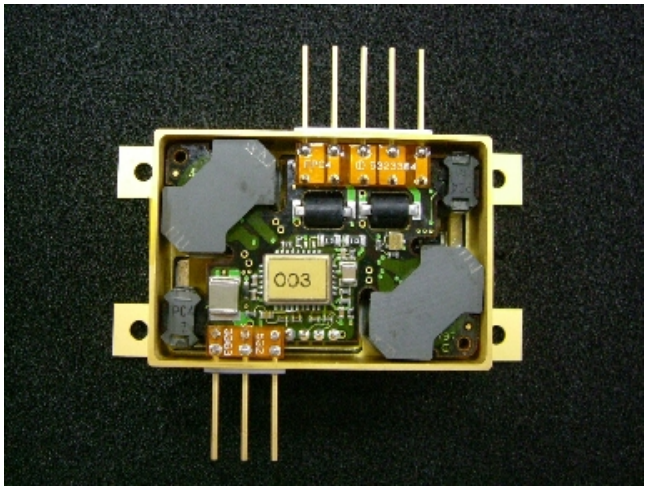
- Conclusion



DC/DC Converter

Background

Requirements :
-High-Reliability
-High-Efficiency
-Small Size

Problems with conventional DC/DC converters :
-Solder Cracks

New DC/DC Converters are needed

Key Technologies

- Triple-Sided Parts Mounting Structure
- Planar Transformer
- Analog ASIC

Features

General

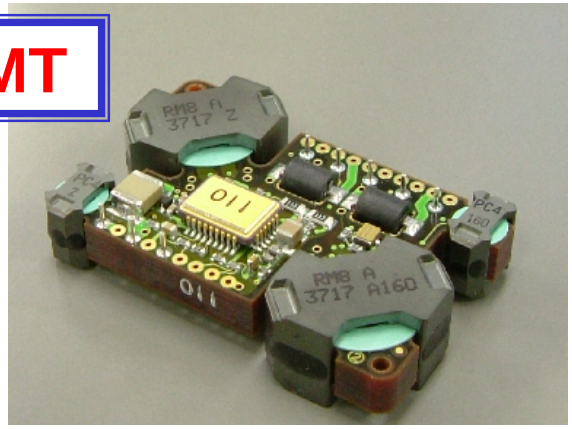
- Input Voltage : +26V to +55V
- Dual Outputs : ±15V±2%, 1.3A
- Fixed Frequency : 100kHz (typical.)
- Efficiency : up to 88%
- Size : 58mm(W)×40mm(D)×17mm(H)
- Weight : 150g MAX

Environment

- Operating Temperature : -55℃ to +125℃
- Mechanical Shock : 100G, 6ms
- Vibration : 20G, Sin, 20Hz-2kHz

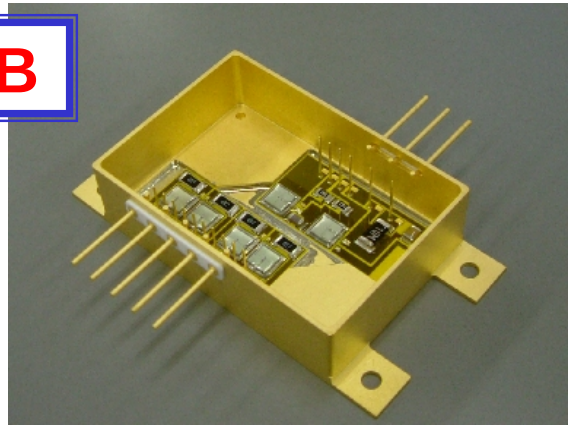
Structure

SMT

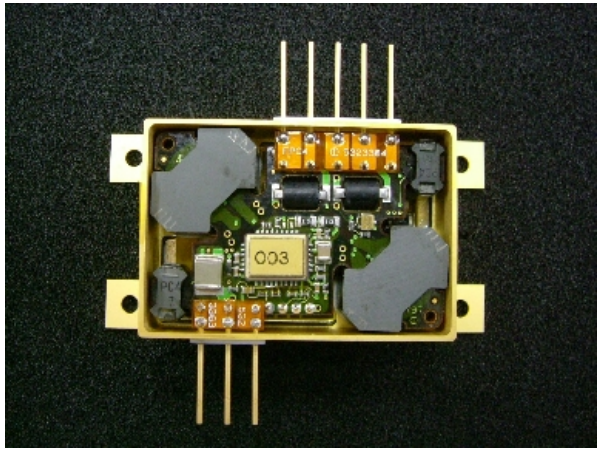


Planar Transformer with Parts

COB



Header with Power Parts

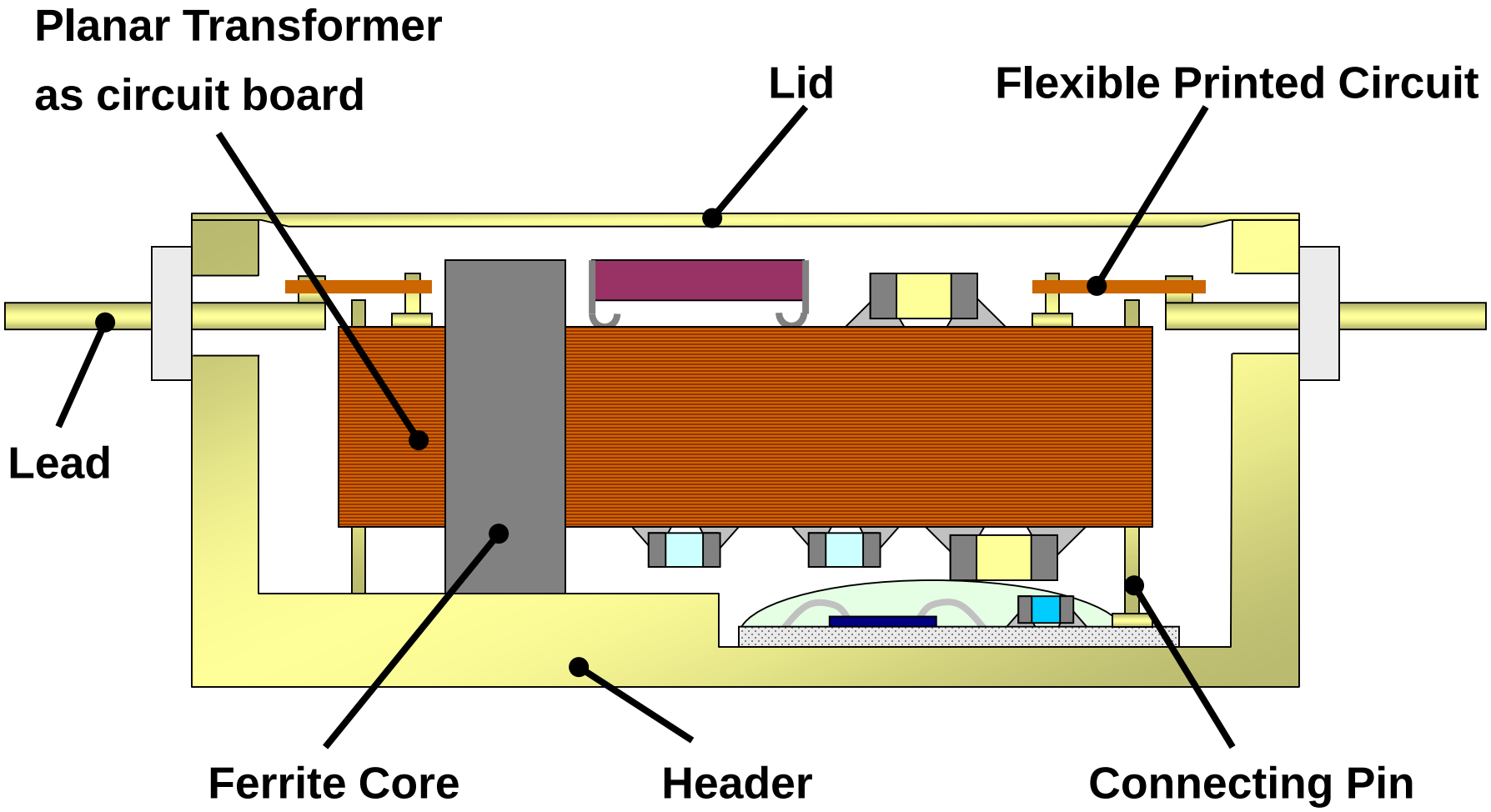


COB:Chip on Board

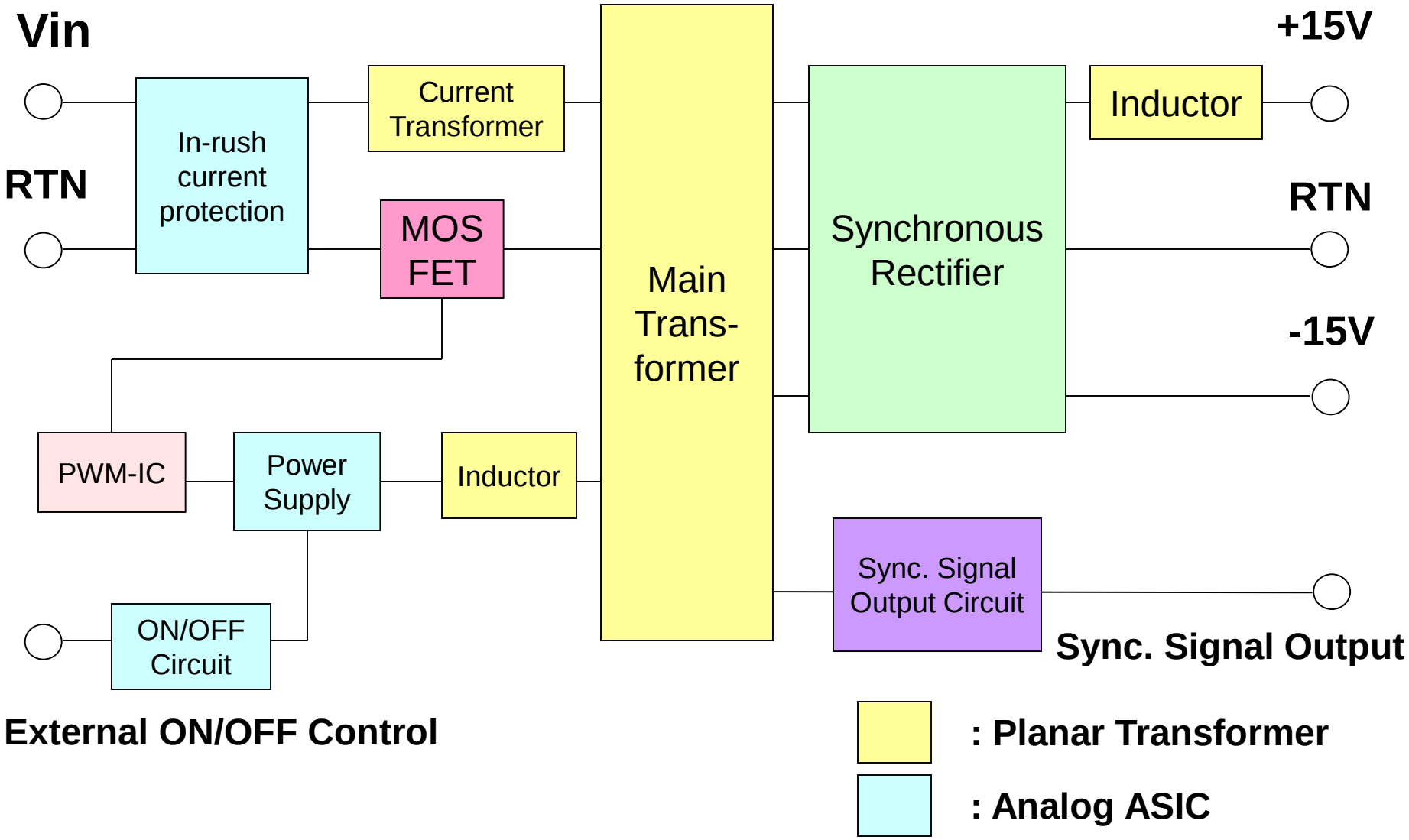
SMT:Surface Mount Technology

SMT + COB = Triple-Sided Parts Mounting Structure

Structure of DC/DC Converter (Cross Section)



Functional Block Diagram



Key Elements

1.Planar Transformer

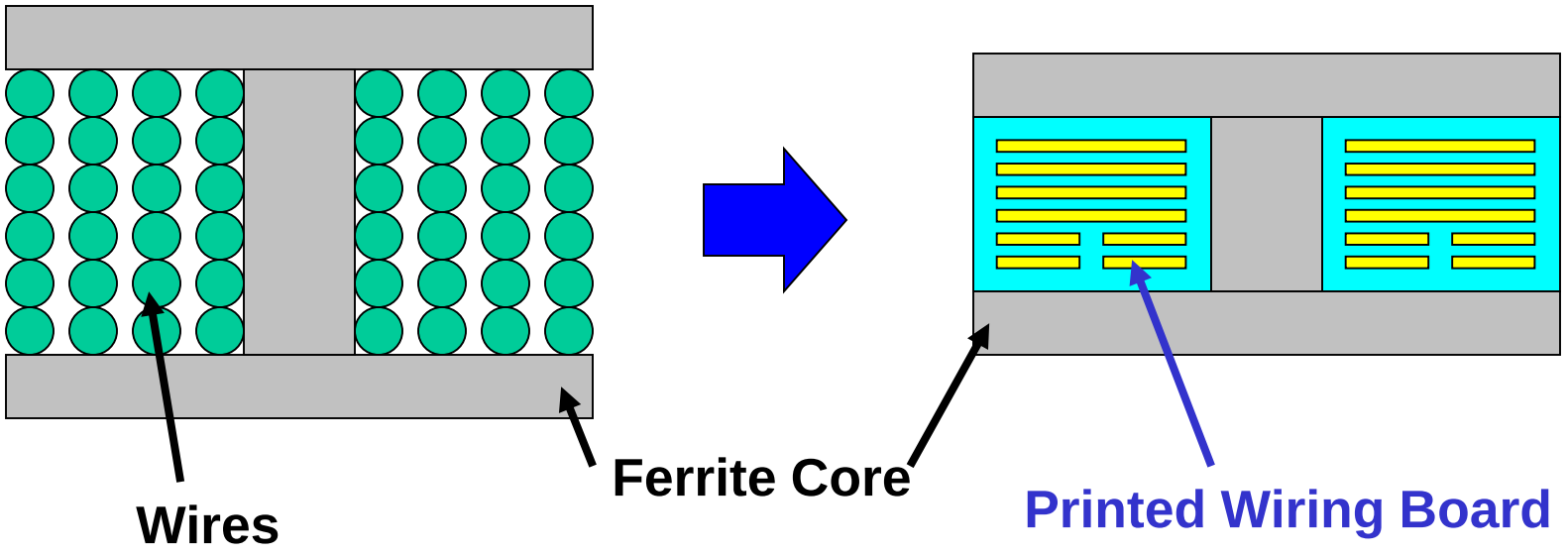
2.Analog ASIC

1-1.Concept of Planar Transformer

Replace wires with PWB stacks (32 layers)

Wire-Wound Transformer

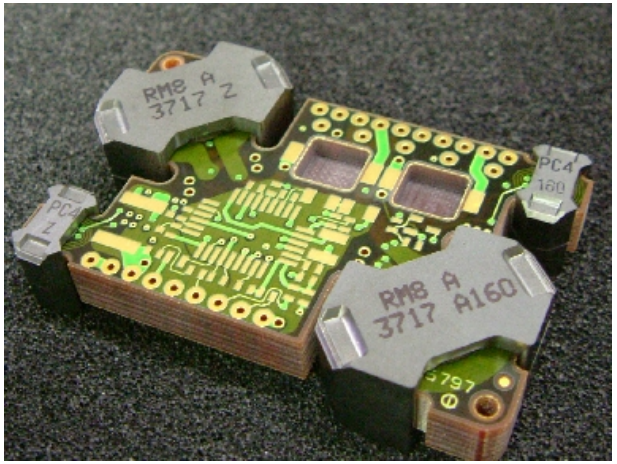
Planar Transformer



Key Elements (continued)

1-2.Feature of Planar Transformer

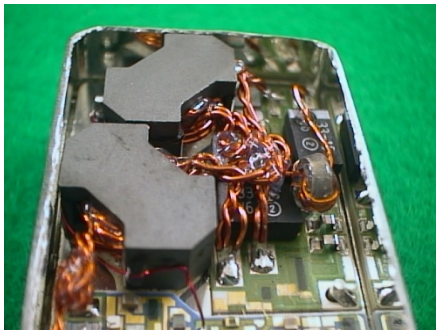
- No micro-soldering and wiring
- Circuit integration
- Double-sided parts mounting
- Uniform characteristics
- Good thermal conductivity
- Low height



Planar Transformer

Improve Reliability

- Vulnerable to cracks on micro-soldering area
- Vulnerable to scratches to Wires
- Characteristics not uniform
- Weak thermal conductivity



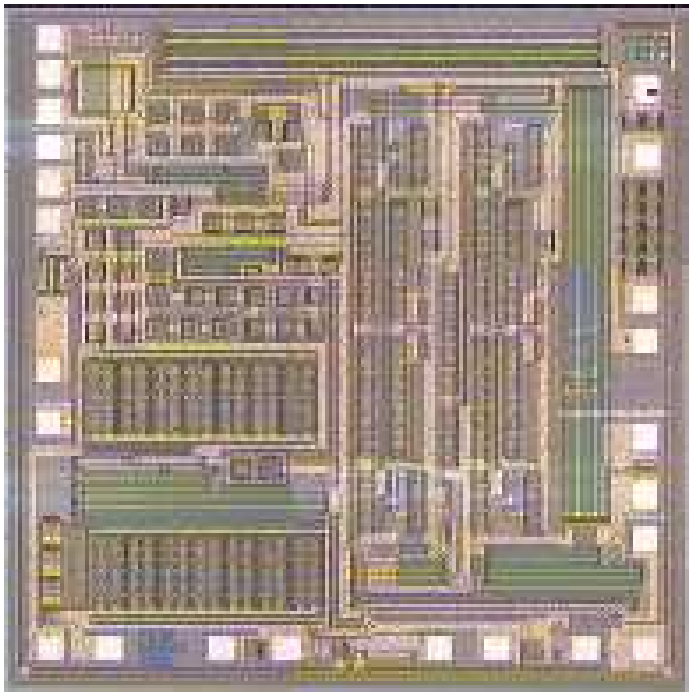
Conventional example

Key Elements (continued)

2-1. Analog ASIC

Features

- 47 low loss devices
- Radiation-proof design



Functions

- Power supply to PWM-IC
- Overload and overvoltage protections
- External ON/OFF control

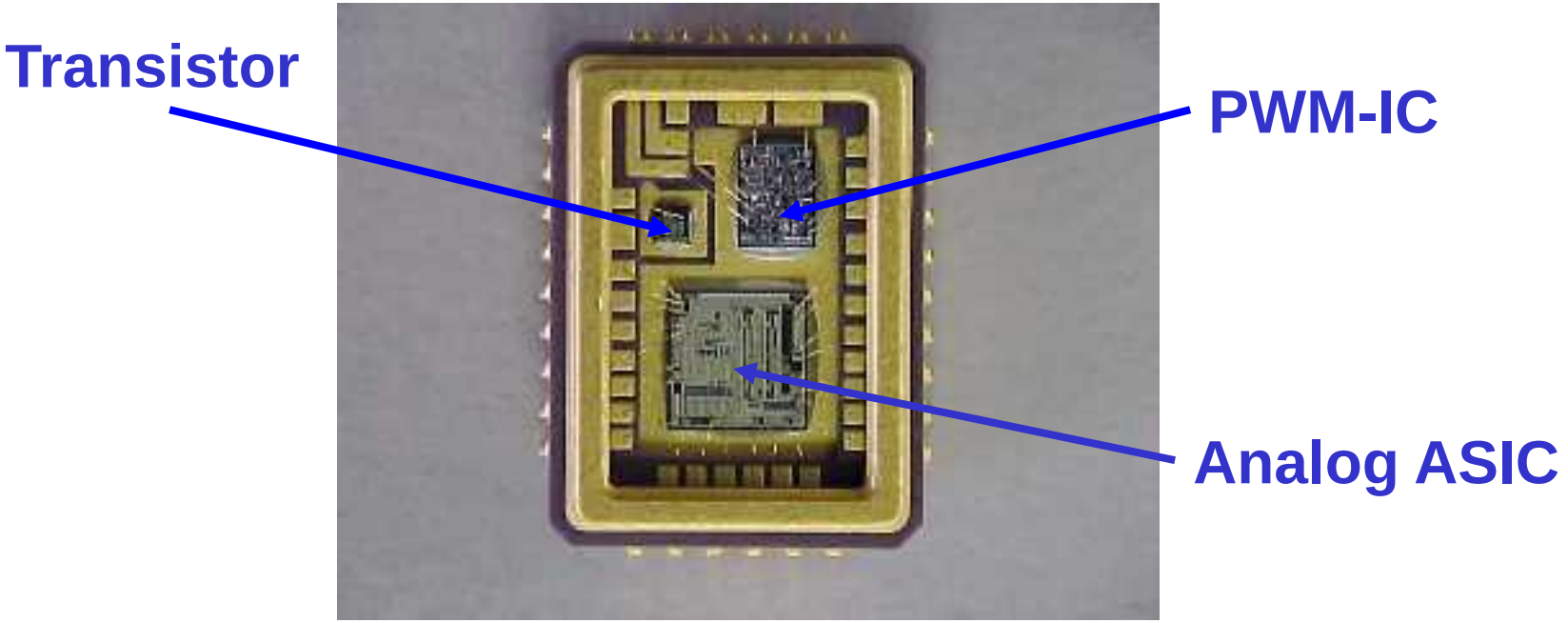
Effect

- 74% footpoint reduction from equivalent discrete devices

Key Elements (continued)

2-2. Package of Analog ASIC

The Analog ASIC is packaged together with a Transistor and PWM-IC chip



Contribute to a miniaturization of DC/DC Converter

Detailed Data

Characteristics

Electrical Characteristics

Parameter	Condition	MIN	TYP	MAX	UNITS
Input Voltage	Continuous	26	50	55	VDC
Output Voltage	—	±14.70	±15.00	±15.30	VDC
Output Current	Vin=26 to 55VDC	±0.3	±1.3	±1.5	A
Output Power	Vin=26 to 55VDC	—	39	45	W
Output Ripple Voltage	Vin=26 to 55VDC	—	80	150	mVpp
Line Regulation	Vin=26 to 55VDC	—	100	300	mV
Load Regulation	Iout=0.2A to 1.5A	—	100	300	mV
Efficiency	Vin=50V,Iout=1.3A	85	88	—	%

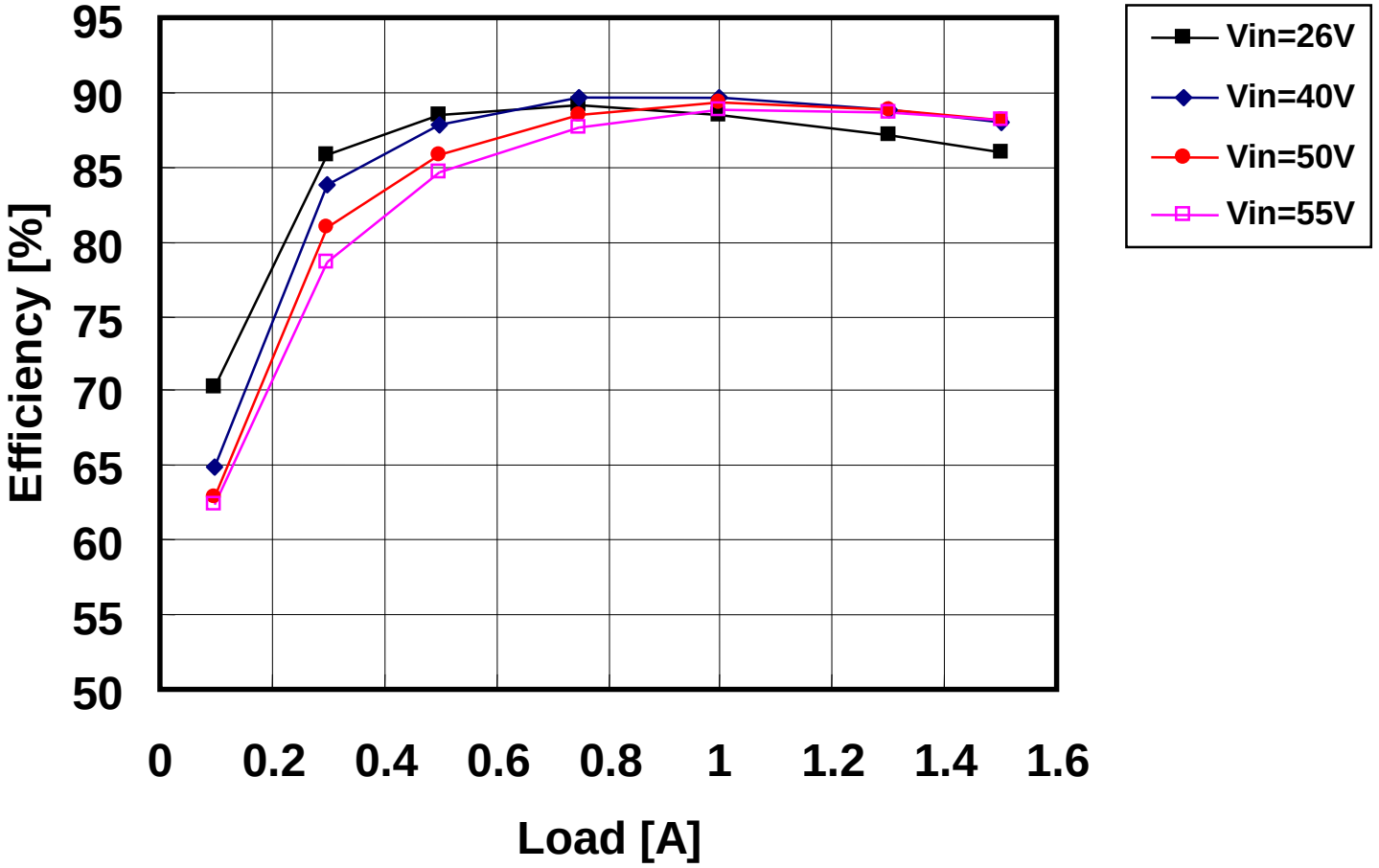
Other Characteristics

Description	Characteristics
Protection	Overload Protection Overvoltage Protection
Function	External ON/OFF Control Synchronous Signal Output
Isolation	500VDC (Input to Output)
Operation Frequency	100kHz Typical

Electrical Test

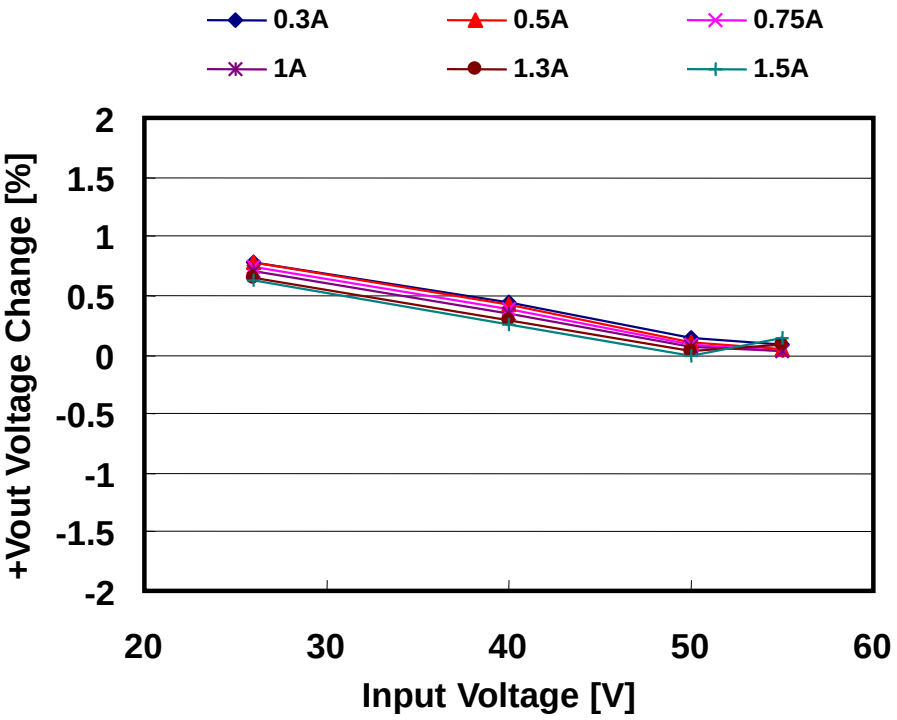
Load versus Efficiency Characteristics

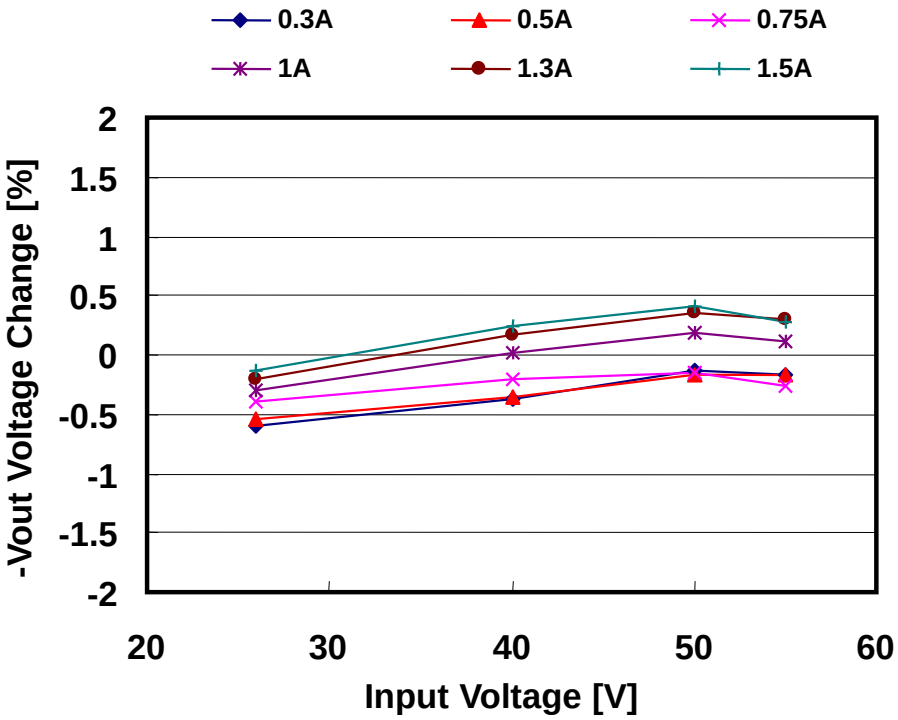
Test result shows efficiency of almost 88%



Electrical Test (continued)

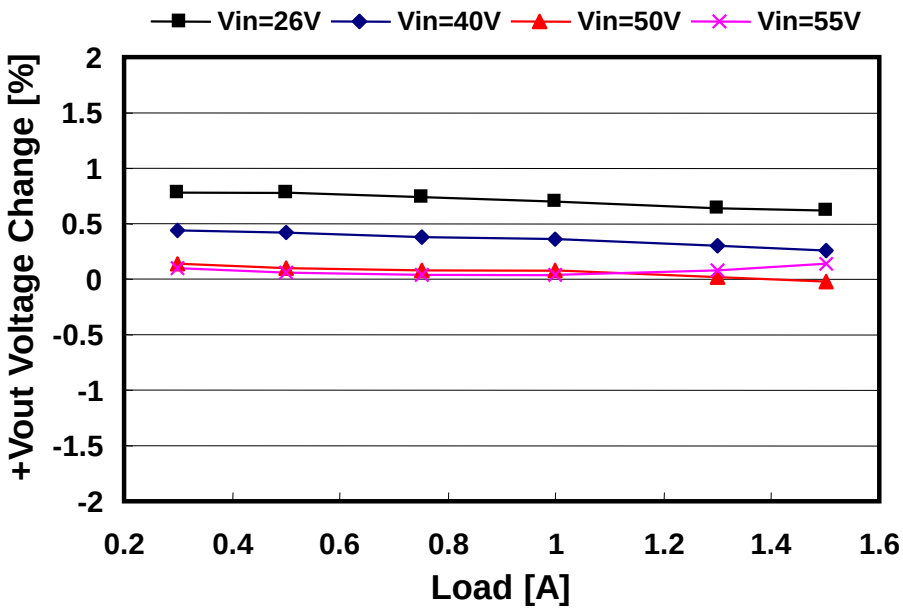
Line Regulation Characteristics

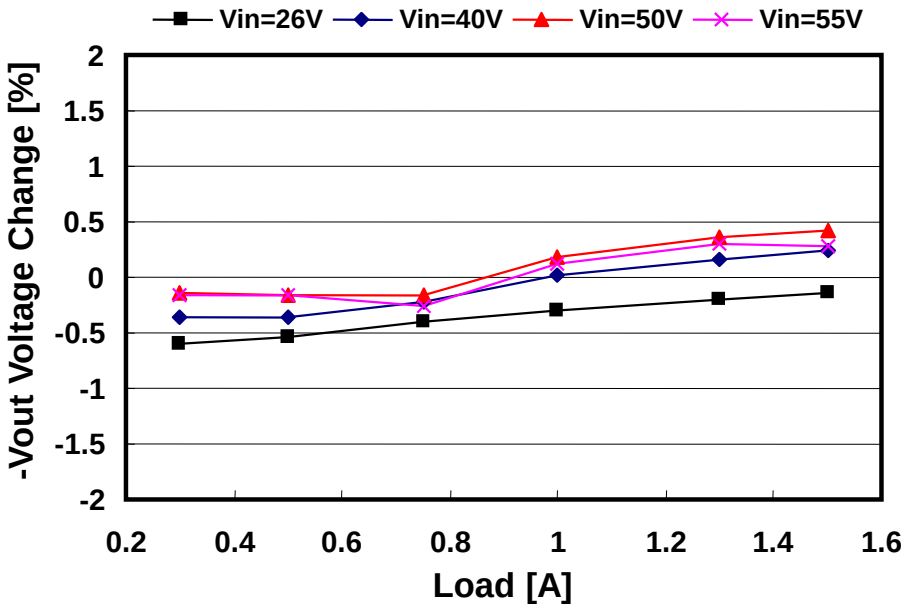




Electrical Test (continued)

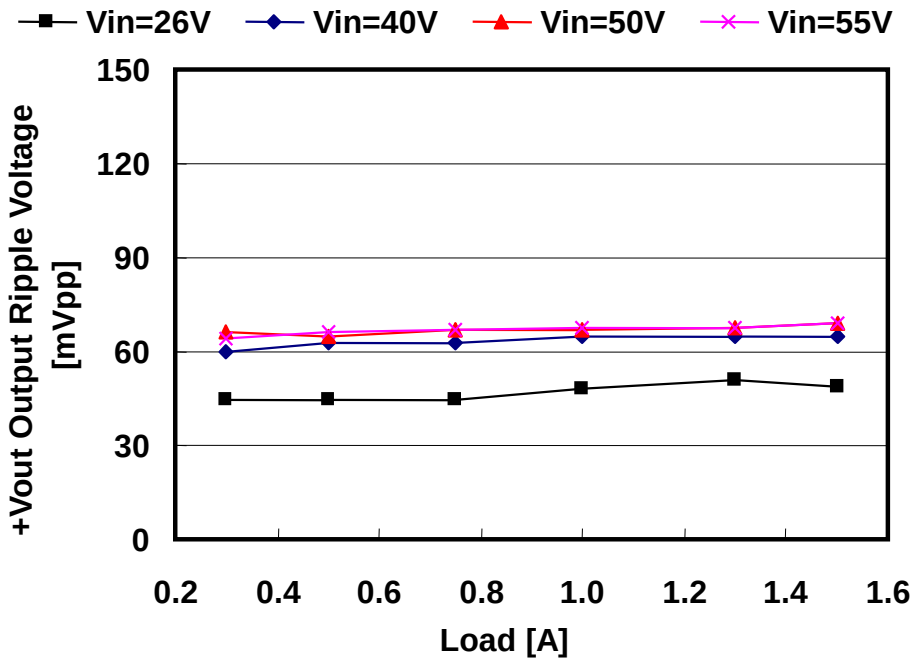
Load Regulation Characteristics

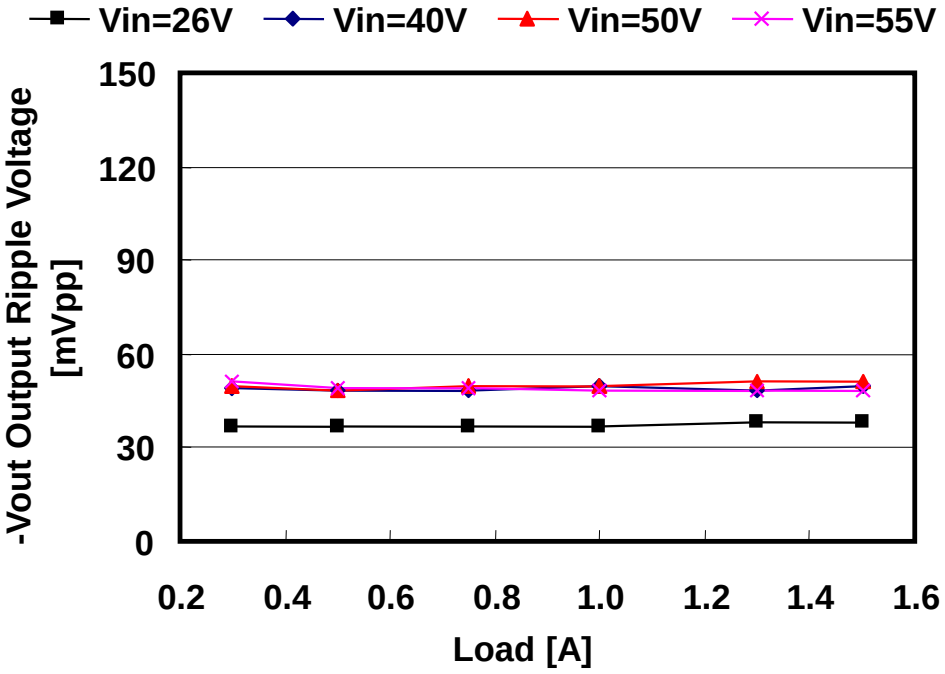




Electrical Test (continued)

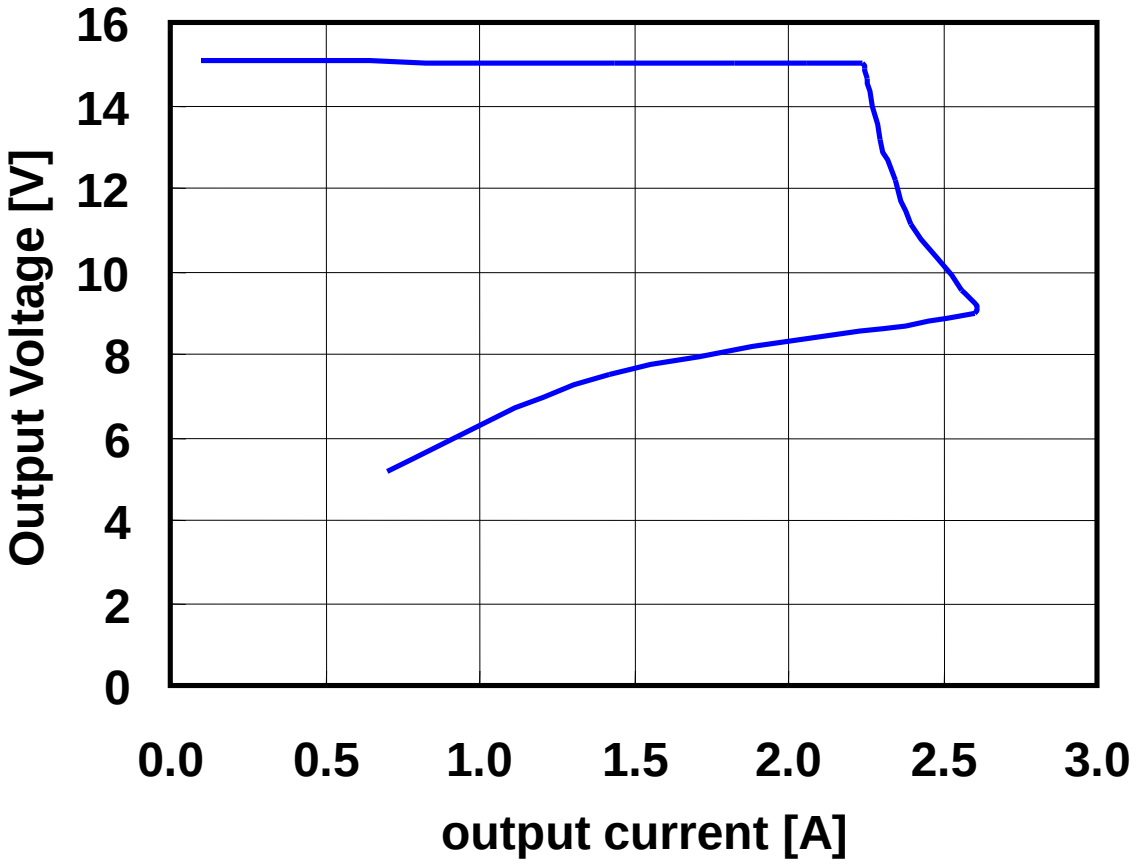
Output Ripple Voltage Characteristics





Electrical Test (continued)

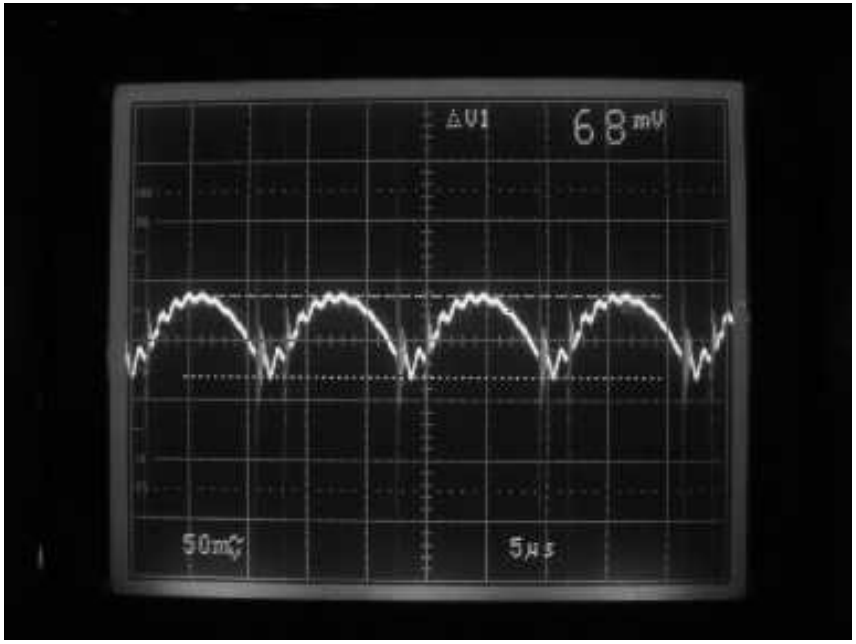
Overload Protection Characteristics



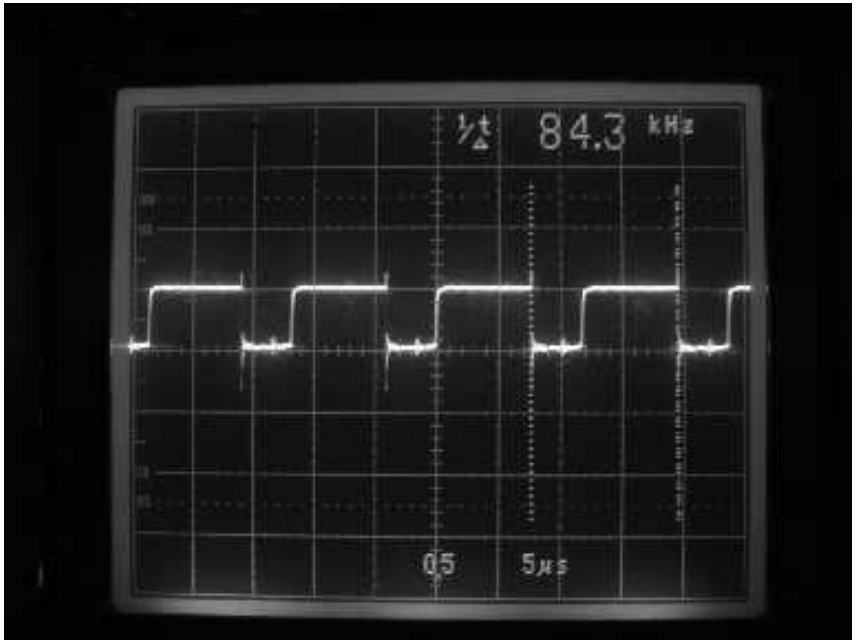
Vin=50V

Electrical Test (continued)

Waveform Photograph



Output Ripple
Vin=50V,Load=1.3A,Tc=25℃



Synchronous Signal
Vin=50V,Load=1.3A,Tc=25℃

Radiation Test

Radiation Data

We have radiation data on the following five items

Device	SEE	TD
PWM-IC	○	○
Shunt Regulator	—	○
Optocoupler	—	○
Analog ASIC	○*	○*
Power MOSFET	○*	○*

***Radiation tests were performed by JAXA.**

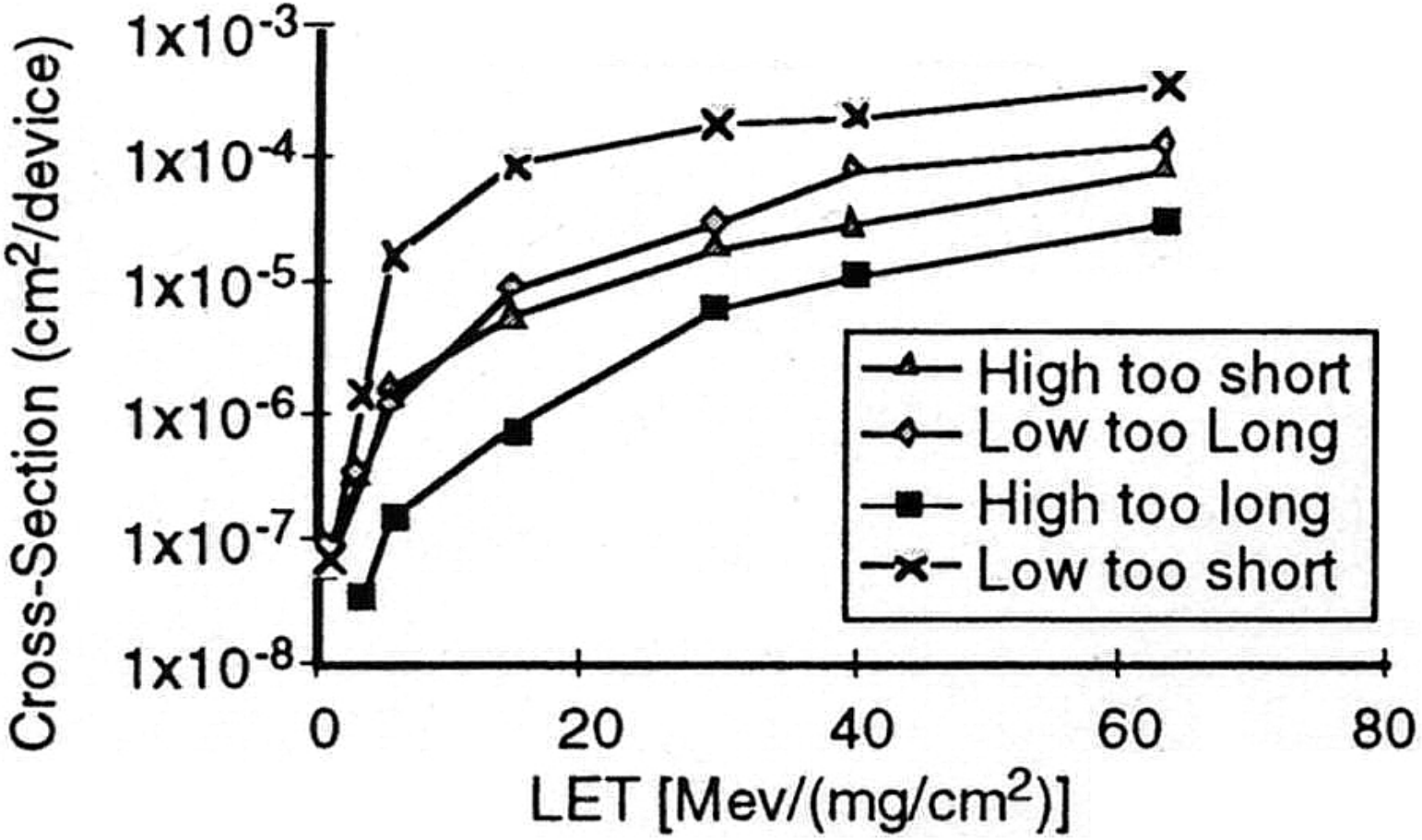
Radiation Test (continued)

SEE Sensitivity of PWM-IC

- Latch-up is not expected in bipolar devices.
- SEU is observed on output pulses as follows:
  - -High too long
  - -Low too short
  - -High too short
  - -Low too long
- SEU will not affect DC/DC Converter outputs.

Radiation Test (continued)

SEU Test Data of PWM-IC



Ref.: "Single Event Effects in Pulse Width Modulation Controllers,"
IEEE Trans. Nucl. Sci.,NS-43,No.6(December 1996)

Radiation Test (continued)

Total Dose Sensitivity of PWM-IC

- Radiation-sensitive parameters are:

  -Output Voltage in the Reference Section

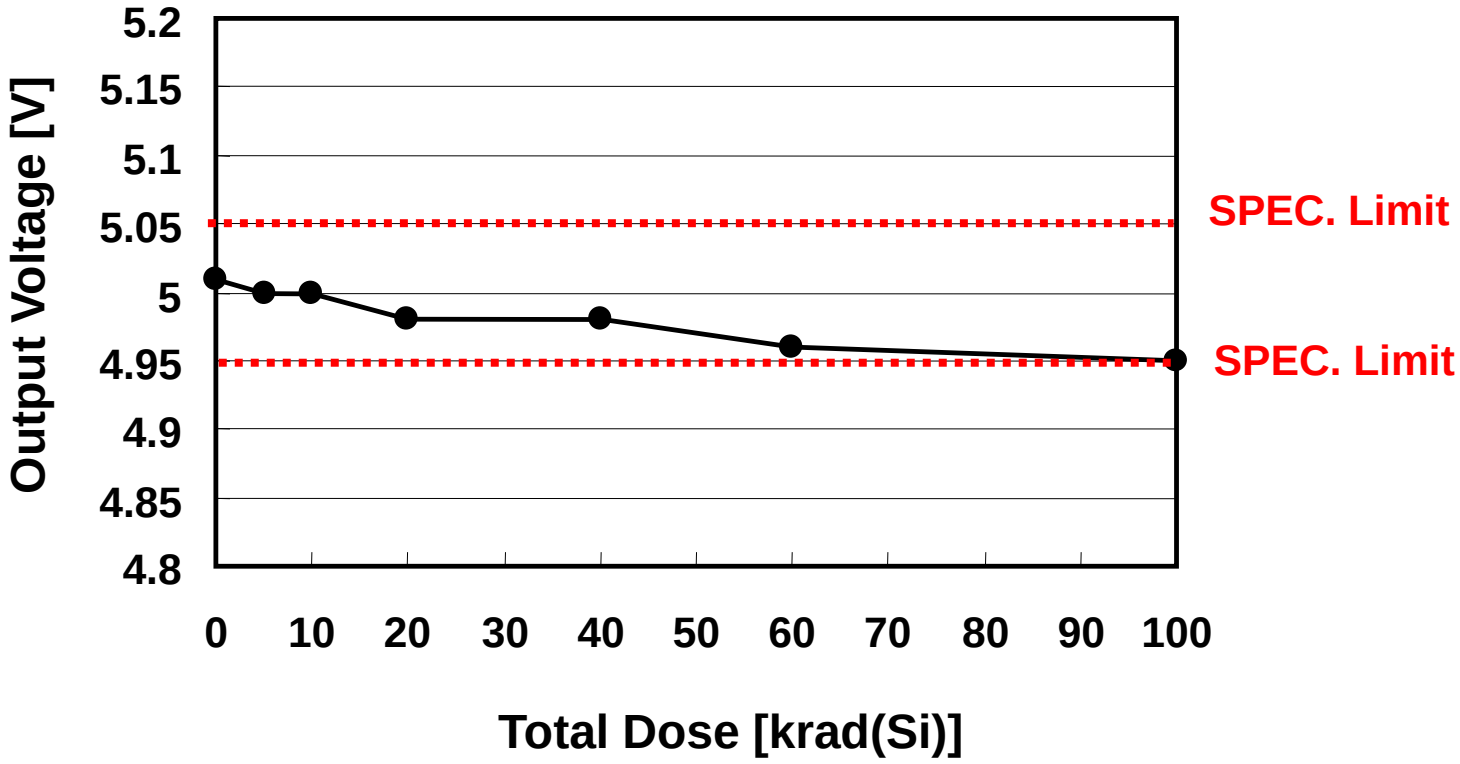
  -Start Threshold in the Under-Voltage Lockout Section

- No significant radiation-sensitivities were observed in other test parameters.

Radiation Test (continued)

Total Dose Test Data1 of PWM-IC

The degradation is within spec.

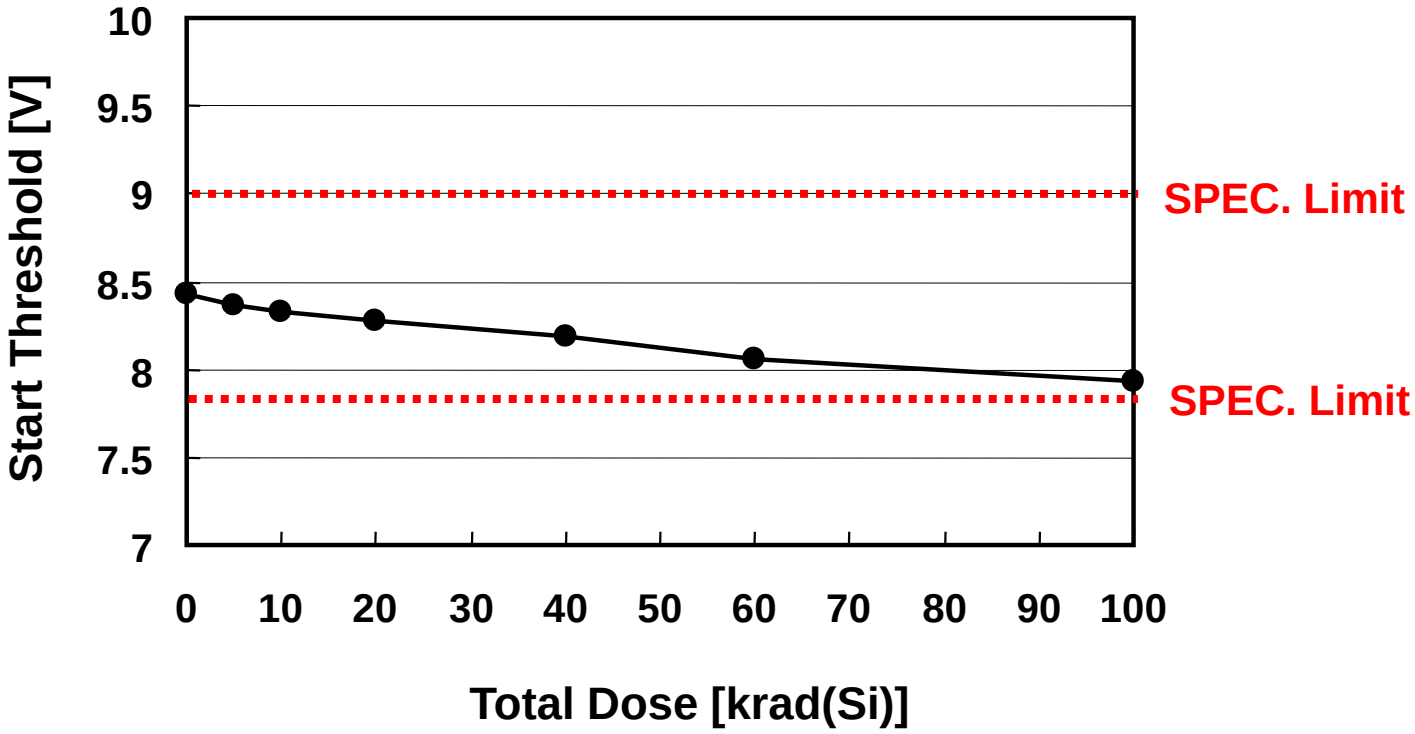


Ref.: ”Radiation Report on FAST/MU3,” Paramax Systems Corporation

Radiation Test (continued)

Total Dose Test Data2 of PWM-IC

The degradation is within spec.



Ref.: ”Radiation Report on FAST/MU3,” Paramax Systems Corporation

Radiation Test (continued)

Total Dose Test Data of Shunt Regulator

No significant sensitivity to radiation

Parameter	Radiation Level, Rads(Si)					Pretest Spec
	0K	25K	50K	75K	100K	
VREF(V)@ VKA=VREF, IK=10mA	2.48756	2.48730	2.48722	2.48723	2.48702	2.400 Min 2.600 Max
IREF(μA)@ IK=10mA, R1=10KΩ,R2=∞	1.40	1.59	1.69	1.76	1.83	8 Max
Ioff(μA)@ VKA=12.5V, VREF=0V	0.020 (Note 1)	0.020	0.020	0.020	0.020	3 Max (Note 2)

NOTES:

1. All Ioff measurements recorded 20Na, attributable to the fixture leakage.
2. At VKA=36.

Ref.: "TID Summary," Vertical Circuits,Inc.

Radiation Test (continued)

Proton Radiation Sensitivity of Optocoupler

- Radiation-sensitive parameter is CTR

- Electrical parameters are similar to 4N49 optocoupler but with much better CTR degradation characteristics against radiation exposure

- The degradation of output current is quite slight at proton radiation of 10^{10} particles/cm^2 (equivalent to about ten-year exposure)

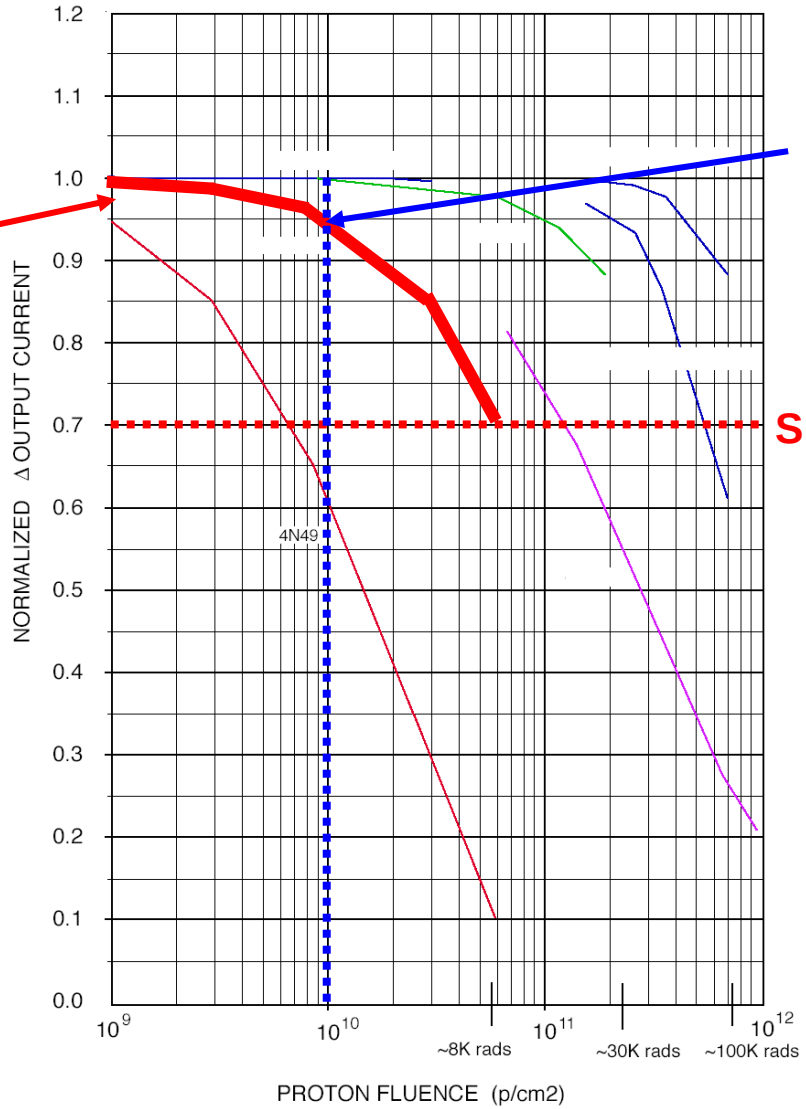
Radiation Test (continued)

Proton Radiation Test Data of Optocoupler

63MeV,
IF=1mA

5% degradation@10^{10}[p/cm^2]
proton fluence

SPEC. Limit



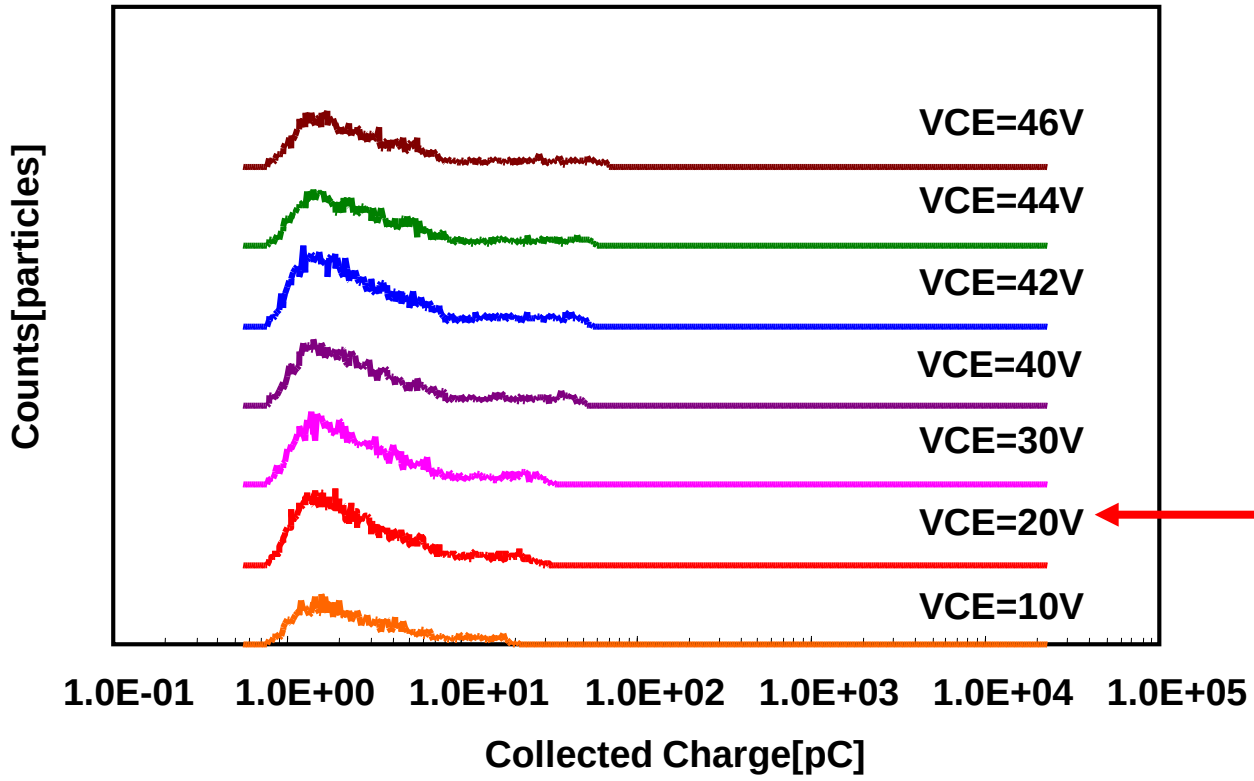
Ref. : Vender Web Site

Radiation Test (continued)

SEB Test Result1 of Analog ASIC

SEB test result of Tr TEG used Analog ASIC

No SEB was observed up to $46V_{CE}$



Ion : $^{58}Ni^{18+}$

Energy: 250MeV

LET : 27.7MeV/(mg/cm²)

Range : 38.95μm

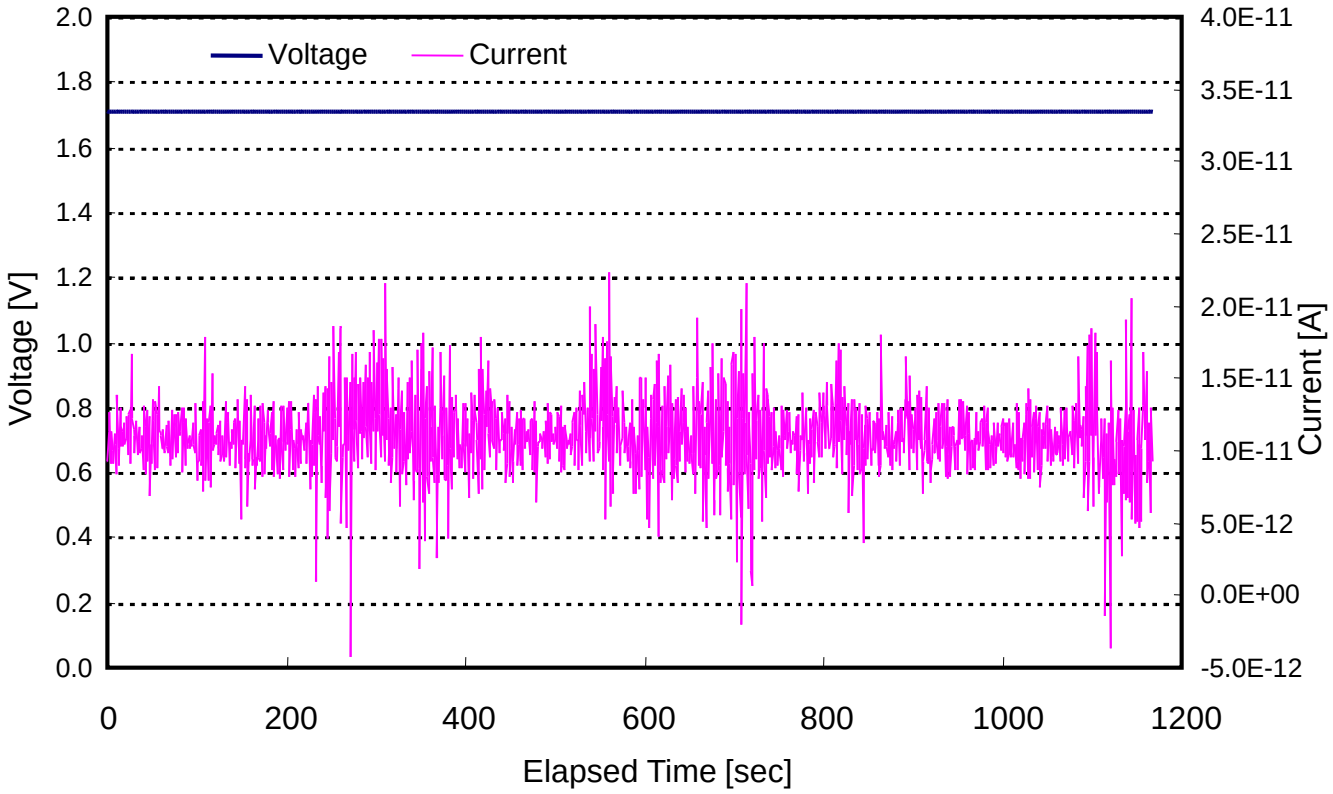
Max Operation Voltage : 20V

Radiation Test (continued)

SEB Test Result2 of Analog ASIC

SEB test result of Analog ASIC

No influence of radiation was observed



Ion : $^{58}Ni^{19+}$

Energy: 381MeV

LET : 25.8MeV/(mg/cm^2)

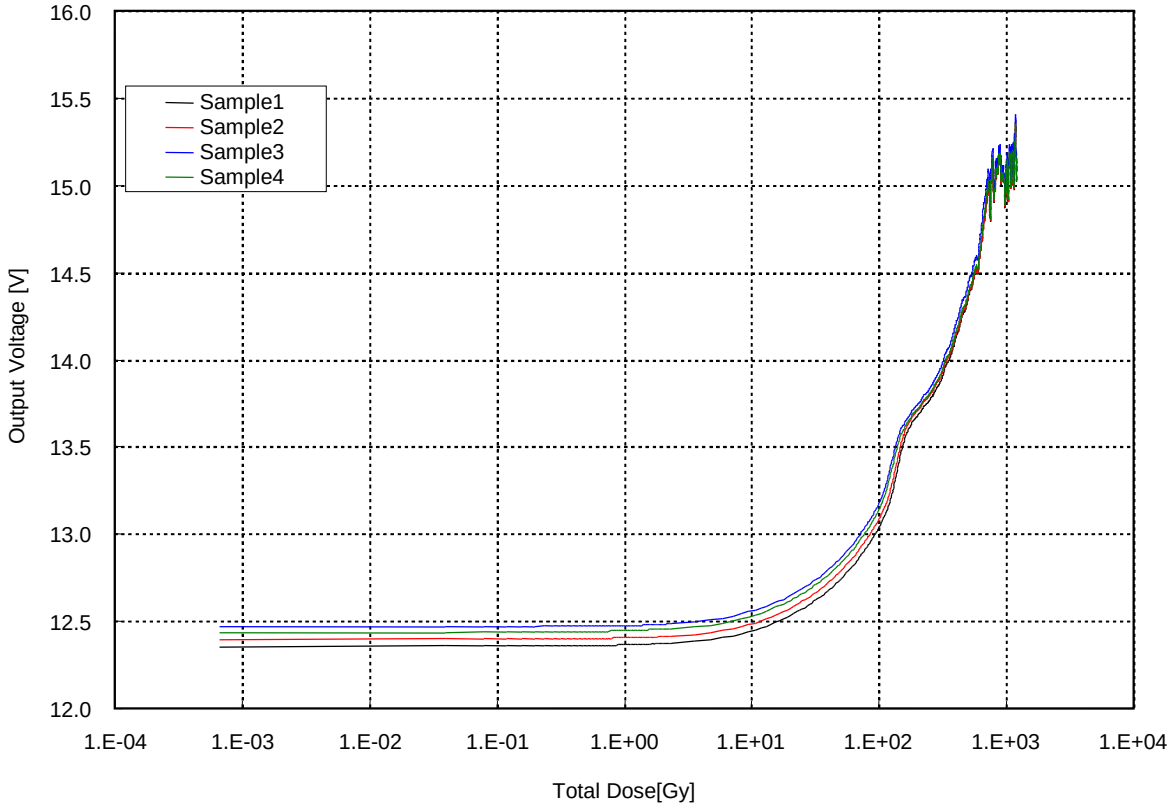
Range : 50.0μm

Radiation Test (continued)

Total Dose Test Result of Analog ASIC

Increase of output voltage was observed

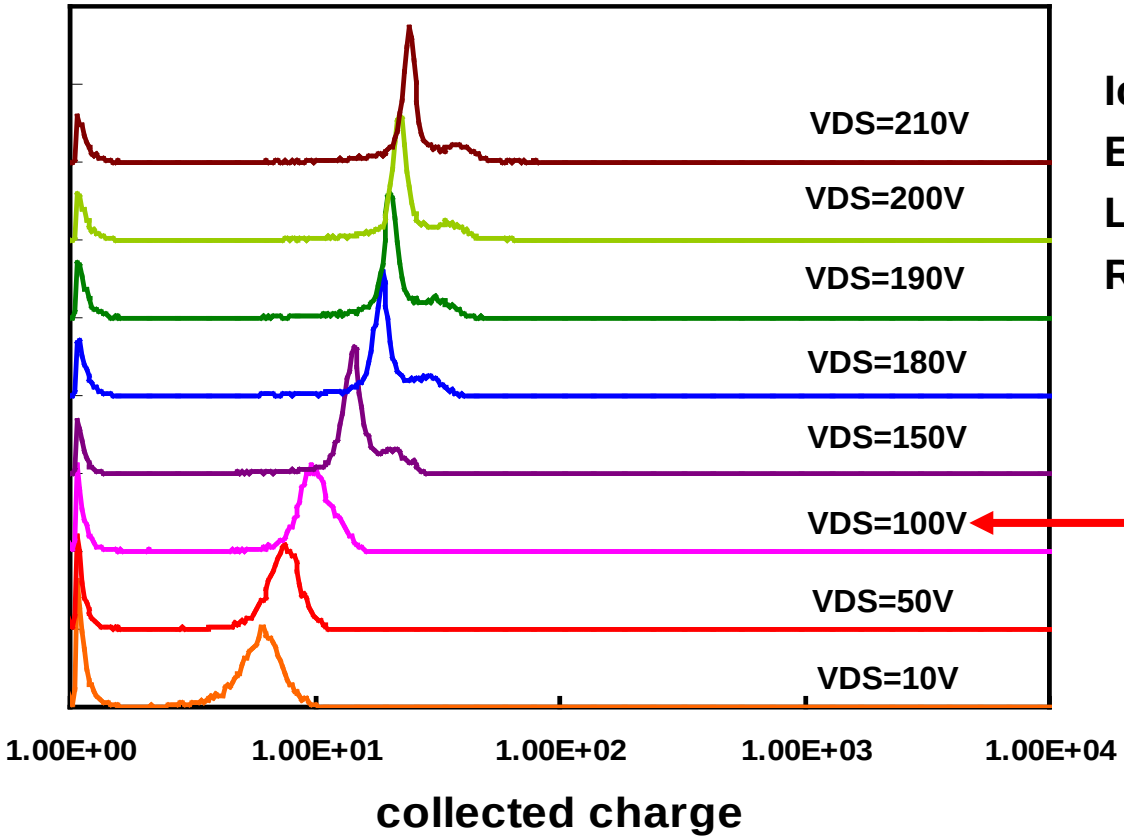
This will not pose a practical problem



Radiation Test (continued)

SEB Test Result of Power MOSFET

No SEB was observed up to $210V_{DS}$



Ion : $^{58}Ni^{18+}$

Energy : 236.53MeV

LET : 28.14MeV/(mg/cm^2)

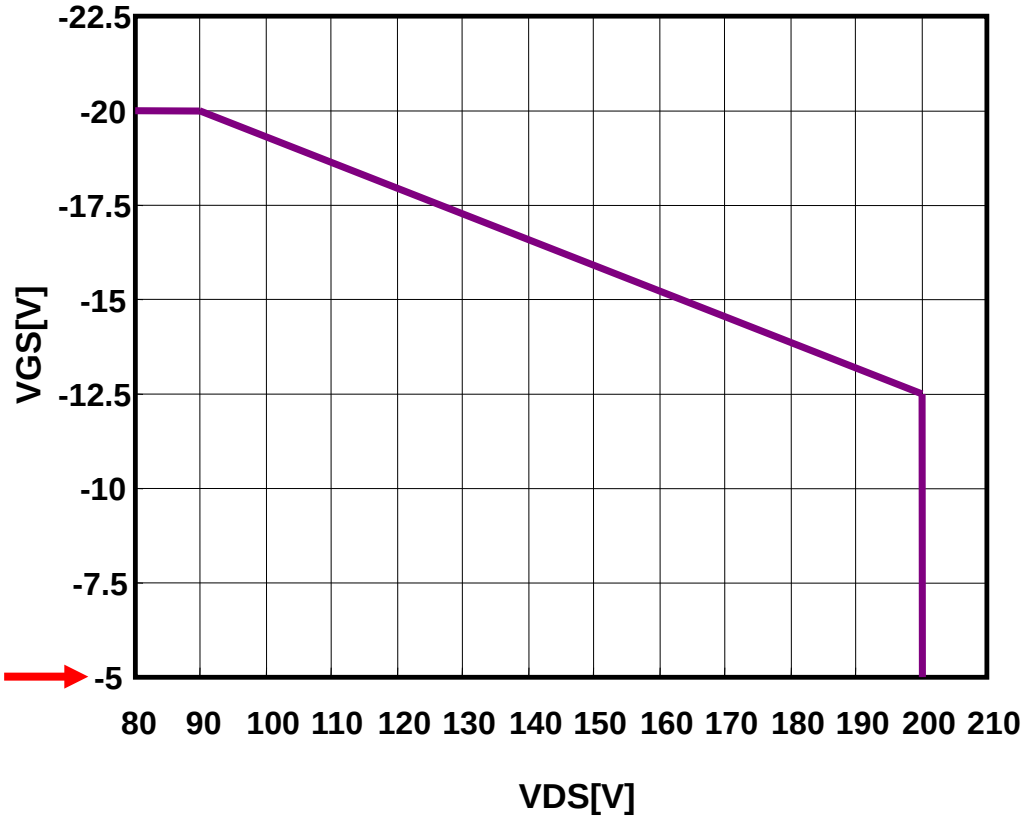
Range : 36.87μm

Max Operation Voltage : 100V

Radiation Test (continued)

SEGR Test Result of Power MOSFET

No Problem because of enough margin for SEGR



Max Operation Voltage : -5V

Ion : $^{58}Ni^{19+}$

Energy : 336.4MeV

LET : 25.36MeV/(mg/cm^2)

Range : 53.5μm

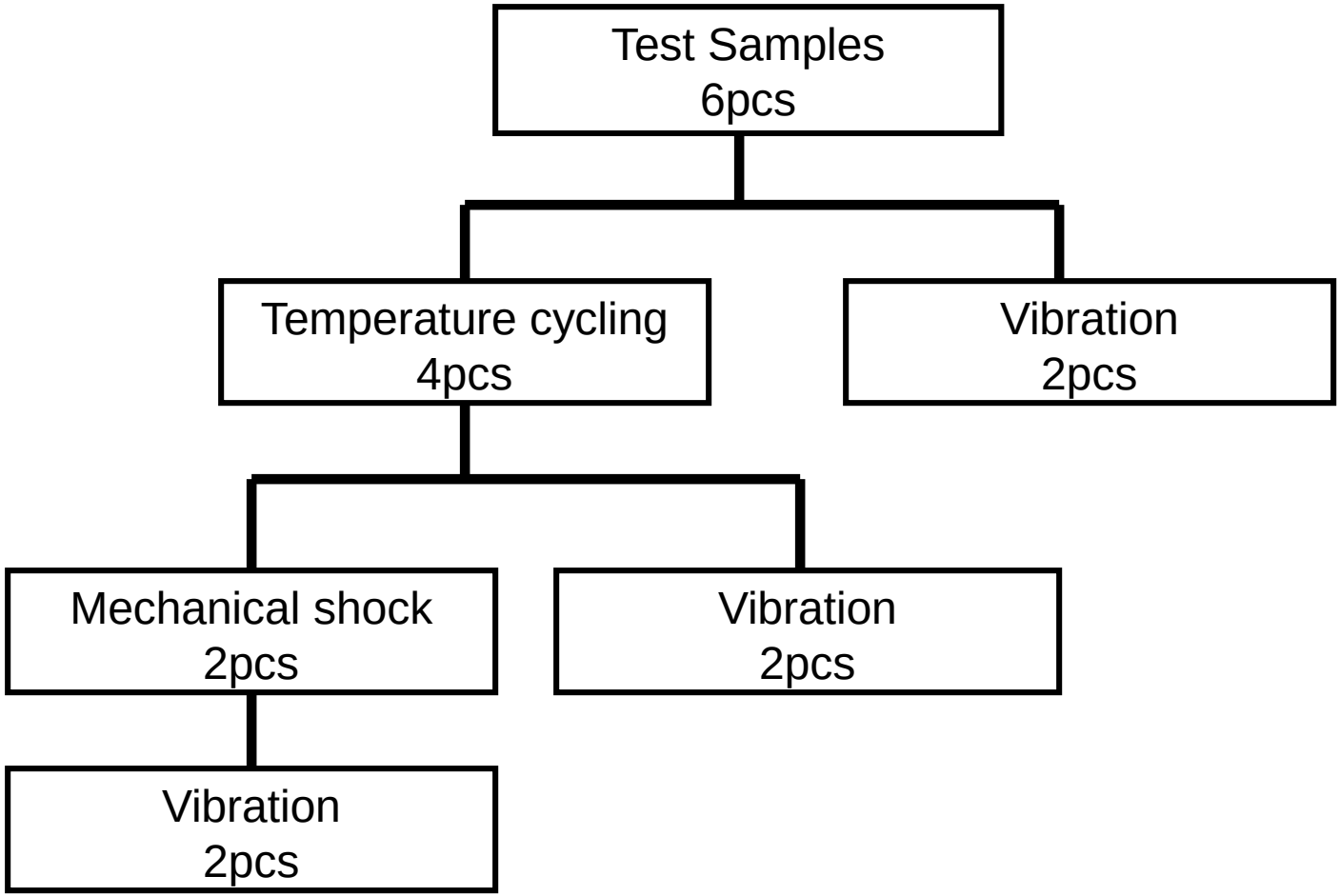
Total Dose Test Result of Power MOSFET

Only small variations in all items

Parameter	Measurement Condition	Unit	Initial	1×10^3Gy	
				VGS=+20V	VGS=-20V
BVDSS	ID=1mA	V	219.3	217.0	218.0
IDSS	VDS=160V	nA	7.15	40.8	24.3
+IGSS	VGS=+16V	nA	56.9	54.4	64.4
-IGSS	VGS=+16V	nA	46.0	32.4	46.0
VGS(th)	ID=1mA, VDS=5V	V	3.03	1.95	2.98
ΔVGS(th)	—	V	—	-0.96	-0.17
RDS(on)	ID=5.5A, VGS=10V	mΩ	57.3	53.0	56.6

Initial Environmental Test

Test Flowchart

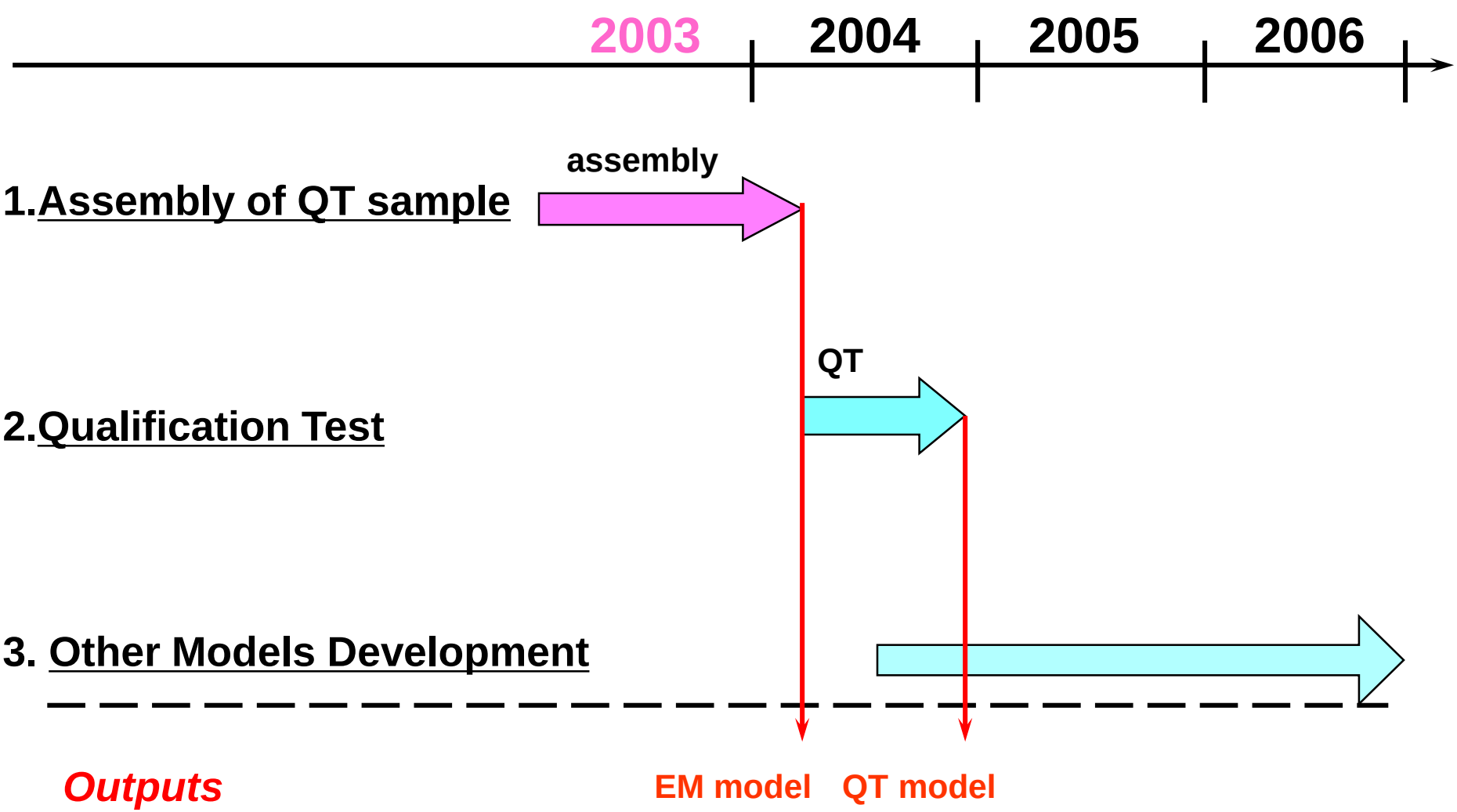


Environmental Test (continued)

Initial Environmental Test Result

Test	Condition	IN	OUT	REJECT
Vibration	883 Method 2007 Condition A 20G, Sin, 3axis	6	6	0
Temperature cycling	883 Method 1010 Condition C -65℃/+150℃,100cyc	4	4	0
Mechanical shock	202 Method 213B Condition C 100G, 6ms,6axis	2	2	0

Development Schedule



Conclusion

- New DC/DC Converter was developed with three key technologies :
  - -Triple-sided parts mounting structure
  - -Planar Transformer
  - -Analog ASIC
- Electrical tests confirmed its satisfactory performance in all respects.
- Initial environmental tests confirm its robustness against vibration, temperature, and shock.
- Qualification tests will start in May, 2004.
- QT Model will be available in November, 2004 to be followed with other models.