**Mx Series – Low Noise EPC for Satellite RF Applications**

**Key Performance Summary:** A summary of key generic performances for both the MA and MB platforms.

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### Parameters and Performance

**Input DC-Bus Voltage:**
- 28V unregulated, 50V, 70V, 100V regulated

**Input Under Voltage Protection:**
- Automatic shut-down if input drops below a threshold. Auto restart or UVF latch is possible. ±1V sensitivity

**Output 1**
- $V_{OUT}$: 1 to 10V fixed, ±1% initial setting & temperature BOL

**Output 2**
- $V_{OUT}$: 2 to 15V fixed, ±1% initial setting & temperature BOL

**Output 3**
- $V_{OUT}$: 3 to 15V fixed, ±1% initial setting & temperature BOL

**Output Sequencing**
- Output 3 (designated negative output) will reach regulation first at turn on before Outputs 1 & 2 begin to rise. It will remain in regulation until Outputs 1 & 2 decays to near zero volt before it begins to fall when powered down.

**Efficiency**
- ±2% EOL radiation and aging; Iout: 0 to 1000 mA, 6W max

**Isolation**
- Each output is independently regulated and power-up and power-down to ensure no cross-regulation and cross-talk radiation and aging effects. Each output can be configured to meet output voltage levels up to 15V and any current level up to 1A.

**Overload and Short Circuit Protection**
- All outputs can withstand a continuous short circuit and overload conditions. No-Load Operation will not cause excessive over voltage or damage.

**Mechanical & Environmental Properties**
- ±2% EOL radiation and aging; Iout: 0 to 1000 mA, 6W max

**Output Power**
- MA: 5W max; MB: 15W max (slightly higher power is possible)

**Output Configuration**
- Outputs are orderly sequenced during power-up and power-down to ensure proper biasing for RF amplifier devices.

**Package Outlines:** Mx series offers two standard package outlines, one for MA platform the other for MB platform.

### References:

1. U.S. Patent No. 4 899 271
2. U.S. Patent No. 5 335 163

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**Platform Applications:**

Mx design platform is intended for low RF (radio frequency) power design applications requiring power up to 15W. The platform is developed specifically for sensitive RF equipment onboard a spacecraft, i.e., receivers, transmitters, beampos, low noise amplifiers (LNAs), and up/down converters. Mx design platform is designed for continuous operations in radiation environments that are presented to commercial, military and scientific missions operating in long term geosynchronous (GEO), medium earth (MEO) and low earth (LEO) orbits.

**Proven Design Heritage**

The power buses the IR design team has experience with are as follows:

- Alcatel SPACEBUS 3000, 50V
- Alcatel SPACEBUS 4000, 100V
- Astrium EUROSTAR 2000, 28-43V
- Astrium EUROSTAR 3000, 50V
- ISRO (Indian Space Research Organization), 26-43V
- BSS (Boeing Satellite Systems), HS601 HP
- ESA (European Space Agency), 28V

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**Platform Description**

Mx series is a radiation hardened multiple output DC-DC converter design platform that can be adapted to most satellite input and output power requirements. The design topology allows simple component changes in the primary section to accommodate different bus voltages. While most design applications require power up to 15W, the platform has adequate design margin to accommodate slightly higher combined output power than 15W. The platform includes ON/OFF telecommand (TC)/telemetry (TLM) design that can be readily adapted to most major satellite interface requirements. The Mx series also includes a hold-up capacitor bank and electrical circuitry to ensure proper turn-on and turn-off timing among the outputs, a critical biasing sequence for GaAs FET devices commonly used for RF power amplifiers.

Two standard assembly outlines exist. MA platform is for output power up to 5W. MB platform with a slightly larger outline is for output power of up to 15W. Open board PCB style construction is chosen to facilitate design adaptation and design changes as needed. Proprietary design simulation tools and design analysis templates are created to quickly and accurately provide performance projection and design tradeoffs where decision in design changes can be made with a high level of confidence. The platform offers RF equipment designers the ability to react and incorporate last minute design changes with very little or no impact to program schedule.

**Design Description**

Functional block diagram shown in Figure 1 represents the design topology for both the MA and MB platforms. The differences are highlighted by the shaded blocks. They include the primary voltage stage, power transformer and output rectification scheme. While triple output designs are common for most applications, the platform can easily be configured to accommodate any number of outputs i.e., 2, 4 or more, with the limitation being the total combined output power requirements.

**Design Topology**

Both the MA and MB designs deploy dual voltage regulation stages, one in the primary and one in the secondary. Regulation in the primary uses current mode control topology to maximize efficiency. The topology also offers inherent current regulation and primary over-current protection. Regulation in the primary is built around a switch flyback transformer and simple output rectification/filter design configuration. This simplifies the converter design which minimizes components count and size. The MB platform accommodates higher output power requirements that are greater than 5W. A patented Hy-bridge rectifier (Ref. 1, back page) topology and integrated components count and size. The MB platform accommodates higher output voltage headroom and maximize efficiency. The regulator circuit is a single switch flyback transformer and simple output rectification/filter design configuration. This simplifies the converter design which minimizes components count and size. The MB platform accommodates higher output power requirements that are greater than 5W. A patented Hy-bridge rectifier (Ref. 1, back page) topology and integrated magnetic (Ref. 2, back page) in conjunction with two-switch half bridge power stage is chosen to maximize converter’s efficiency. Unlike the traditional method of rectification, the proprietary Hy-bridge rectifier arrangement yields only one voltage drop which reduces output rectification losses and increases efficiency.

**Outputs Timing**

Outputs 1 and 2 are typically designated as positive outputs. Each output commences to turn on only after Output 3 to ensure adequate hold-up time for Output 3 to maintain regulation until Outputs 1 and 2 decay to safe level nearing zero volt during a power-down sequence. Samples of turn-on and turn-off waveforms are shown in Figure 2.

**Input/Output Power Train**

Both the single-switch flyback and two-switch half bridge can easily accommodate a wide range of input voltages. The switch elements are selected based on the operating input bus voltage and dynamic transient conditions. Transformer design and turn-ratios are adjusted accordingly. The output rectifiers may require different voltage and current ratings. MA and MB assembly outline designs have taken into account all the changes in component footprints due to the deviations in input and output requirements. The established PCB layout and dimensions can normally be maintained for most design applications.

**Input Filter**

The Mx platform also includes an input filter design that yields very low reflected line noise and is expected to satisfy EMI/EMC requirements of most major satellite power buses. While the design will change to accommodate different input bus voltages, the change in the filter components have very little or no impact on the assembly layout. Figure 3 presents an example of an actual conducted emission performance.

**TC/TLM/Temperature Telemetry**

The TC/TLM interfaces are isolated from one another and from any other functional and input/output terminals within the converter. Temperature telemetry is available and can be included as required.
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Design Topology
Both the MA and MB designs employ dual voltage regulation stages, one in the primary and one in the secondary. Regulation in the primary uses current mode control topology to maximize efficiency. The topology also offers inherent current regulation and primary over-current protection. Regulation in the primary is built around a standard PWM controller with known performance characteristics. Voltage regulation is performed on the internal 10V supply via a bootstrap winding of the power transformer (XFMR). All primary circuitries including PWM controller and gate drive circuitry are powered by an internal 10V linear regulator upon power up. The internal 10V supply takes over all biasing responsibility upon achieving regulation.

Primary input circuitries are galvanically isolated from the secondary output via a power transformer. Secondary voltages of the transformer are stepped down, rectified and filtered feeding downstream output regulators. All outputs are independently regulated by linear voltage regulators which offer inherent excellent noise and regulation performances. The regulators use discrete components with a bipolar transistor as a pass element to minimize voltage headroom and maximize efficiency. The regulator circuit is a proprietary design that has been used successfully for many design applications. Extremely low output noise and high CS rejection are possible with the dual stage regulation scheme. Guaranteed end of life (EOL) performances for voltage accuracy and regulation can be demonstrated through worst case and aging design analysis. Please refer to Table 1 (back page) for specific performance limits. Example of actual output noise performance is shown in Figure 2.

Platform Description
Mx series is a radiation hardened multiple output DC-DC converter design platform that can be adapted to most satellite input and output power requirements. The design topology allows simple component changes in the primary section to accommodate different bus voltages. While most design applications require power up to 10W, the platform has advanced design margin to accommodate slightly higher combined output power than 15W. The platform includes ON/OFF telecommand (TC)/telemetry (TLM) design that can be readily adapted to most major satellite interface requirements. The Mx series also includes a hold-up capacitor bank and electrical circuitry to ensure proper turn-on and turn-off timing among the outputs, a critical biasing sequence for GaAs FET bank and electrical circuitry to ensure proper turn-on and turn-off requirements. The Mx series also includes a hold-up capacitor bank and electrical circuitry to ensure proper turn-on and turn-off requirements. The Mx platform also includes an input filter design that yields very low reflected line noise and is expected to satisfy EMI/EMC requirements of most major satellite power buses. While the design will change to accommodate different input bus voltages, the change in the filter components have very little or no impact on the assembly layout. Figure 3 presents an example of an actual conducted emission performance.

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Input/Output Power Train
Both the single-switch flyback and two-switch half bridge can easily accommodate a wide range of input voltages. The switch elements are selected based on the operating input bus voltage and dynamic transient conditions. Transformer design and turn-ratios are adjusted accordingly. The output rectifiers may require different voltage and current ratings. MA and MB assembly outline designs have taken into account all the changes in component footprints due to the deviations in input and output requirements. The established PCB layouts and dimensions can normally be maintained for most design applications.

Input Filter:
The Mx platform also includes an input filter design that yields very low reflected line noise and is expected to satisfy EMI/EMC requirements of most major satellite power buses. While the design will change to accommodate different input bus voltages, the change in the filter components have very little or no impact on the assembly layout. Figure 3 presents an example of an actual conducted emission performance.

TC/TLM/Temperature Telemetry:
The TC/TLM interfaces are isolated from one another and from any other functional and input/output terminals within the converter. Temperature telemetry is available and can be included as required.

Figure 1: Mx Series Functional Block Diagram

Figure 2: Output Noise/Ripple Performance
MA vs. MB
While both the MA and MB platforms deploy the same basic design topology, there are some differences in the power train designs. MA platform uses a single switch flyback power stage with standard flyback transformer and simple output rectification/filter design configuration. This simplifies the converter design which minimizes components count and size. The MB platform accommodates higher output power requirements that are greater than 5W. A patented Hy-bridge rectifier (Ref. 1, back page) topology and integrated magnetic (Ref. 2, back page) in conjunction with two-switch half bridge power stage is chosen to maximize converter efficiency. Unlike the traditional method of rectification, the proprietary Hy-bridge rectifier arrangement yields only one voltage drop which reduces output rectification losses and increases efficiency.

Outsuts Timing
Outputs 1 and 2 are typically designated as positive outputs. Each output commences to turn on after Output 3 (negative output) reaches regulation band by way of an ‘Enable’ signal generated by internal circuitries. A capacitor bank with sufficient energy storage capacity is added preceding Output 3 to ensure adequate hold-up time for Output 3 to maintain regulation until Outputs 1 and 2 decay to safe level near zero volt during a power-down sequence. Samples of turn-on and turn-off waveforms are shown in Figure 2.

Input Voltage/Current Range
All three output regulators can accommodate wide output voltage/current range with the limitation on the combined output power. Please refer to Table 1 (back page) for more detail voltage and current limitations for each of the outputs. The regulators use a common design with slight design variations for different voltage and current requirements.

Figure 3: Input EMC Conducted Emission Performance

Figure 3: Input EMC Conducted Emission Performance
Ma Series – Low Noise EPC for Satellite RF Applications

Key Performance Summary: A summary of key generic performances for both the MA and MB platforms.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input DC-Bus Voltage</td>
<td>28V unregulated, 50V, 70V, 100V regulated</td>
</tr>
<tr>
<td>Input Under Voltage Protection</td>
<td>Automatic shutdown if input drops below a threshold. Auto restart or UVF latch is possible.</td>
</tr>
<tr>
<td>Output 1</td>
<td>Up to 100 mA feed, ±1% voltage regulation &amp; temperature BOL, ±1% EOL &amp; aging, output: 0 to 1000 mA, 4W max</td>
</tr>
<tr>
<td>Output 2</td>
<td>Up to 100 mA feed, ±1% voltage regulation &amp; temperature BOL, ±1% EOL &amp; aging, output: 0 to 1000 mA, 4W max</td>
</tr>
<tr>
<td>Output 3</td>
<td>Up to 100 mA feed, ±1% voltage regulation &amp; temperature BOL, ±1% EOL &amp; aging, output: 0 to 1000 mA, 4W max</td>
</tr>
<tr>
<td>Output Power</td>
<td>MA: 5W max; MB: 15W max (slightly higher power is possible)</td>
</tr>
<tr>
<td>Package Outlines:</td>
<td>Mx Series – Low Noise EPC for Satellite RF Applications</td>
</tr>
<tr>
<td></td>
<td>Reliability &lt;180 FIT at 60˚C per MIL-HDBK-217F, Notice F2, based on 0.035FIT for soldering</td>
</tr>
</tbody>
</table>

Electrical Parameter Performance

- **EMC – Conducted Emission on Input**: 0 – 100 KHz: 80 dbµArms; 100 KHz – 10 MHz: -20 db/dec; 10 MHz – 50 MHz: 40 dbµArms
- **EMC – Conducted Emission on Output**: <1 mVrms, frequency domain of 100 Hz – 50 MHz
- **Telemetry – ON/OFF Status**: Bi-level derived from +5V line
- **Tele-command**: High level pulse command (latching relay)
- **Isolation**: Input, output and tele-command port are isolated from one another
- **Efficiency**: 65 to 75% depending on input DC and output voltage
- **No-Load Operation**: No-load operation will not cause excessive over voltage or damage
- **Overload and Short Circuit Protection**: All outputs can withstand a continuous short circuit and overload conditions
- **Output Sequencing**: Output 3 (designated negative output) will reach regulation first at turn on before Output 1 & 2 begin to rise. It will remain in regulation until Outputs 1 & 2 decay to near zero level before it begins to fall when powered down.
- ** ±2% EOL radiation and aging**: ±1% EOL power-up and power-down to ensure regulation design
- **Proven Design Heritage**: Outputs are orderly sequenced during power-up and power-down to ensure proper biasing for RF amplifier devices
- **Conducted susceptability (CS) rejection**: As high as ±100 dB as a result of a two stage regulation design
- **Output Power**: MA: 5W max; MB: 15W max (slightly higher power is possible)
- **±2% End-of-life (EOL) accounting for temperature, radiation and aging effects**: ±1% EOL power-up and power-down to ensure regulation design
- **Guaranteed voltage accuracy and regulation**: ±1% EOL power-up and power-down to ensure regulation design
- **Two design patents are deployed to maximize efficiency performance**: ±1% EOL power-up and power-down to ensure regulation design
- **Outputs are orderly sequenced during power-up and power-down to ensure proper biasing for RF amplifier devices**: ±1% EOL power-up and power-down to ensure regulation design
- **Isolated ON/OFF tele-command and ON/OFF status telemetry with a latching relay**: ±1% EOL power-up and power-down to ensure regulation design
- **Two established assembly outlines for differing output powers**: ±1% EOL power-up and power-down to ensure regulation design
- **All components are space flight qualified to class S**: ±1% EOL power-up and power-down to ensure regulation design

Features:
- Accommodates most major power buses, 28V, 50V, and 100V
- Integrated input filter to ensure EMC/EMI compatibility to most satellite power buses
- No limitation on number of outputs though most requirements are triple output configuration
- Each output can be configured to meet output voltage levels up to 15V and any current level up to 1A
- Guaranteed voltage accuracy and regulation to within ±1% begin-of-life (BOL) and ±2% end-of-life (EOL) accounting for temperature, radiation and aging effects
- No cross regulation and cross talk as each output is independently regulated
- Two design patents are deployed to maximize efficiency performance
- Efficiency is in the range of 65 to 75% depending on output voltage, current and power
- Each output uses linear regulator enabling output noise to be less than 1 mVRMS
- Conduction susceptability (CS) rejection is as high as ±100 dB as a result of a two stage regulation design

Platform Applications: Mx design platform is intended for low RF (radio frequency) power design applications requiring power up to 150W. The platform is developed specifically for sensitive RF equipment onboard a spacecraft, i.e., receivers, transmitters, beamers, low noise amplifiers (LNAs), and up/down converters. Mx design platform is designed for continuous operations in radiation environments that are presented to commercial, military and scientific missions operating in long term geosynchronous (GEO), medium earth (MEO) and low earth (LEO) orbits.

Proven Design Heritage: The power buses the IR design team has experience with are as follows:
Alcatel SPACEBUS 3000, 50V  •  Alcatel SPACEBUS 4000, 100V  •  Astrium EUROSTAR 2000, 26-43V  •  Astrium EUROSTAR 3000, 50V  •  Space Systems Loral FS1300, 97-100V  •  Lockheed Martin A2100, 54.5-70V  •  NPQM Express A, 23-31V  •  NPOI Express, 22-31V  •  Orbital STAR-1, 1A-36V  •  Orbital STAR-2, 23-36V  •  ISRO (Indian Space Research Organization), 24-43V  •  BSS (Boeing Satellite Systems), HS601 HP  •  ESA (European Space Agency), 28V

References:
1. U.S. Patent No. 4 899 271
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