

# Mx Series – Low Noise EPC for Satellite RF Applications

## Features

- Accommodates most major power buses, 28V, 50V, 70V, 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
- Conducted susceptibility (CS) rejection is as high as 100 dB as a result of a two stage regulation design
- Outputs are orderly sequenced during power-up and power-down to ensure proper biasing for RF amplifier devices
- Isolated ON/OFF tele-command and ON/OFF status telemetry with a latching relay
- Two established assembly outlines for differing output powers
- All components are space flight qualified to class S



## 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, beacons, 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 • NPOPM Express A, 22-31V • NPOPM Express, 22-33V • Orbital STAR-1, 24-36V • Orbital STAR-2, 23-36V • ISRO (Indian Space Research Organization), 26-43V • BSS (Boeing Satellite Systems), HS601 HP • ESA (European Space Agency), 28V

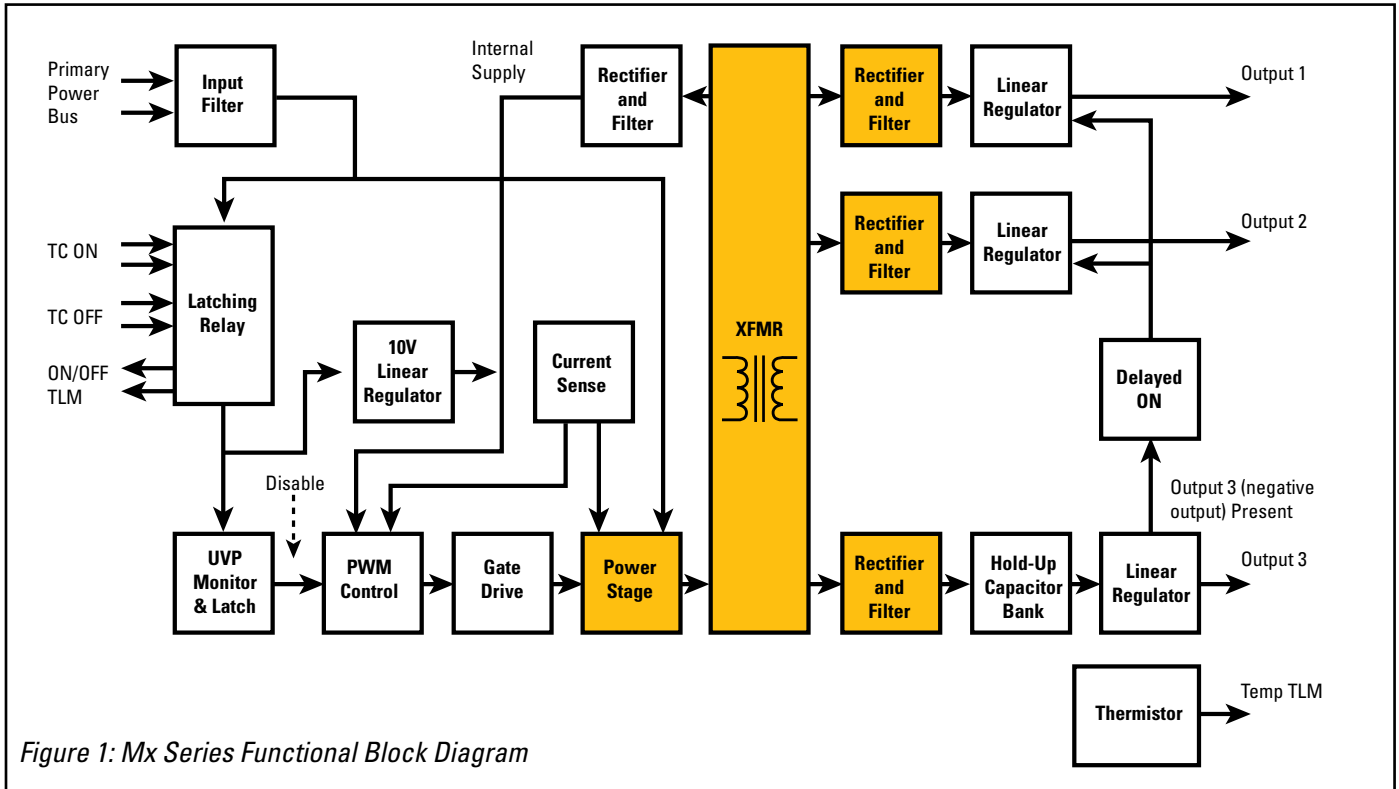


Figure 1: Mx Series Functional Block Diagram

**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 adjustments 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 power 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 standard PWM controller with known performance characteristics in the targeted radiation environments. 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.

All 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**.

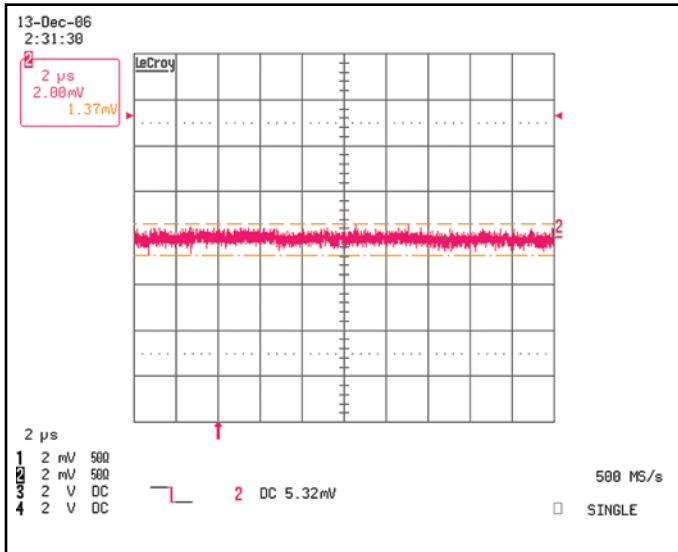


Figure 2: Output Noise/Ripple Performance

### 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 traditional 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 (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 nearing zero volt during a power-down sequence. Samples of turn-on and turn-off waveforms are shown in **Figure 3**.

### Output 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.

### 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 foot prints 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 layouts. Figure 3 presents an example of an actual conducted emission performance.

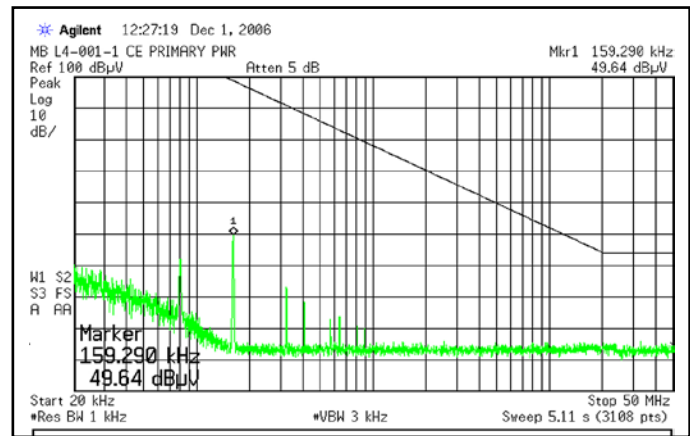


Figure 3: Input EMC Conducted Emission Performance

### TC/TLM/Temperature Telemetry:

The TC/TLM interface is designed to accommodate a standard high level pulse command using latching relay providing the necessary isolation. The telemetry ON/OFF status is bi-level. 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.

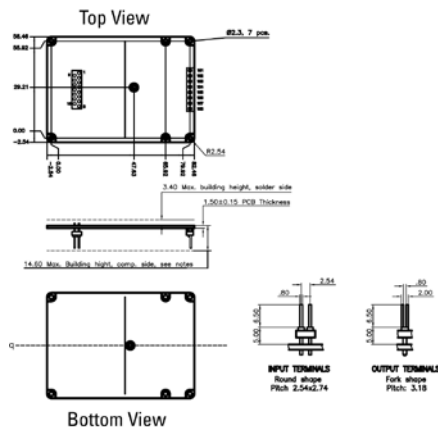
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**Key Performance Summary:** A summary of key generic performances for both the MA and MB platforms.

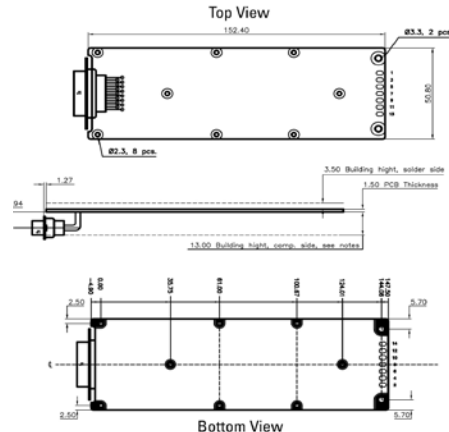
Parameter	Performance
	<b>Electrical</b>
Input DC-Bus Voltage	28V unregulated; 50V, 70V, 100V regulated
Input Under Voltage Protection	Automatic shutdown if input drops below a threshold. Auto restart or UVP latch is possible. $\pm 1V$ hysteresis
Output 1	$V_{OUT}$ : 3 to 15V fixed; $\pm 1\%$ initial setting & temperature BOL, $\pm 2\%$ EOL radiation and aging; Iout: 0 to 1000 mA, 6W max
Output 2	$V_{OUT}$ : 6 to 15V fixed, $\pm 1\%$ initial setting & temperature BOL, $\pm 2\%$ EOL radiation and aging; Iout: 0 to 1000 mA, 6W max
Output 3	$V_{OUT}$ : -2 to -15V fixed, $\pm 1\%$ initial setting & temperature BOL, $\pm 2\%$ EOL radiation and aging; Iout: 0 to 1000 mA, 4W max
Output Power	MA: 5W max; MB: 15W max (slightly higher power is possible)
Overload and Short Circuit Protection	All outputs can withstand a continuous short circuit and overload conditions
No-Load Operation	No-load operation will not cause excessive over voltage or damage
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 decays to near zero volt before it begins to fall when powered down.
Efficiency	65 to 75% depending on input DC bus and output voltage
Isolation	Input, output and tele-command port are isolated from one another, $>1$ Mohms and $<50$ nF
Tele-command	High level pulse command (latching relay)
Telemetry – ON/OFF Status	Bi-level derived from +5V line
Temperature Telemetry	Thermistor type to be determined depending on application
EMC - Conducted Emission on Output	$<1$ mVrms, frequency domain of 100 Hz – 50 MHz
EMC – Conducted Emission on Input	0 – 100 KHz: 80 db $\mu$ Arms; 100 KHz – 10 MHz: -20 db/dec; 10 MHz – 50 MHz: 40 db $\mu$ Arms
EMC – Conducted Susceptibility	$>90$ dB for Iout $>500$ mA; $>100$ dB for Iout $\leq 500$ mA
Inrush current	Primary power sine wave injection of 2 Vp-p, 100 Hz – 50 MHz 200% max. of maximum steady state input current upon TC command upon TC $<10$ A – hot plug-in (4V/ $\mu$ S)
Life Time	15 years minimum in orbit; 18 years design life time for aging
Reliability	$<180$ FIT at 60°C per MIL-HDBK-217F, Notice F2, based on 0.035FIT for soldering and crimp and dissipated power is used instead of rated power for MOSFETS
<b>Mechanical &amp; Environmental Properties</b>	
Temperature	Acceptance: -20°C to +75°C; Qualification: -25°C to +85°C; Cold Start: -40°C Non-Operating: -40°C to +85°C
Size	MA: 85mm x 61mm x 19.5mm or 3.346"x2.402"x0.77" (LxWxH) MB: 152.4mm x 50.8mm x 18mm or 6"x2"x0.71" (LxWxH)
Mass	MA: 75 grams max. MB: 130 grams max.
Vibration	Meets typical launch requirements
Shock	Meets typical launch requirements

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

## MA Assembly Outline



## MB Assembly Outline



### References:

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

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