Platform Power Design for Future Satellite Savings

Mx design platform for space-grade DC-DC converters

Growth in consumer demand for satellite-based services is placing pressure on costs and turnaround times in the space industry. A new switching converter platform satisfying all the performance and documentation requirements for space applications will help constructors respond, by streamlining the design of the power infrastructure.

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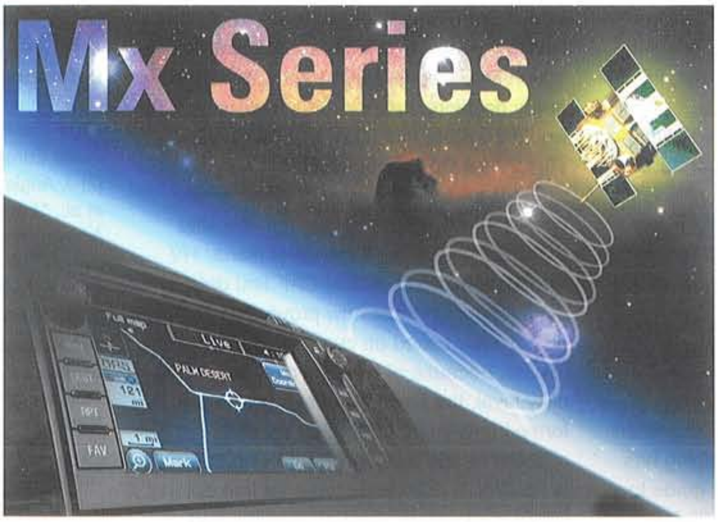

Speeding up design

Hundreds of new satellites are being launched every year, to satisfy rapidly growing demands for services such as personal navigation, broadband multimedia, HDTV, weather data and earth observation. To reduce satellite build times and offer competitive prices, major American, European and Asian constructors are implementing modular, platform-based designs. However components such as DC-DC converters are often still designed individually, since there are no standards governing satellite power buses, and most companies use a proprietary architecture to support special features and differentiate designs. Power bus voltages of leading commercial satellite platforms, for example, range from 22V up to 100V.

The power infrastructure for a satellite is responsible for regulating the charge from the solar panels and delivering the required voltages and power to all the payload and system equipment. Most of the subsystems connected to the satellite's power bus have a unique input/output voltage range and individual requirements for dynamic behaviour. They also tend to have customised tele-command (TC) and telemetry (TLM) interfaces. In practice, no two DC-DC converters are alike.

In addition to the workload involved in designing and building each converter individually, meeting space program requirements for qualification and documentation is also highly labour-intensive and time-consuming. Activities typically include preliminary/critical design review meetings, thermal analysis, stress analysis, reliability analysis, worst case analysis, failure mode effect analysis, radiation susceptibility analysis, acceptance and qualification test procedures/reports, monthly program reports, updated program schedule, weekly status update, and other dedicated program-management functions.

Meeting all of these requirements creates a lengthy development cycle for power converters, with significant implications for cost and scheduling. Typical delivery lead time for flight models (FM) may range from 12 to 18 months, or longer in some instances, depending on complexity and last minute changes in requirements. In practice these deliverable documents and requirements for program review and design review meetings often become the pacing items when design changes occur.

Platform design and flexibility

To solve these challenges and accelerate the design and build of new satellites, International Rectifier has proposed the Mx design platform for space-grade DC-DC converters. The platform can be quickly adapted to meet most satellite input and output power requirements up to 15W. There is also adequate design margin to accommodate slightly higher combined output power if necessary. The platform is developed specifically for sensitive onboard RF equipment, such as receivers, transmitters, beacons, low noise amplifiers (LNAs), and up/down converters.

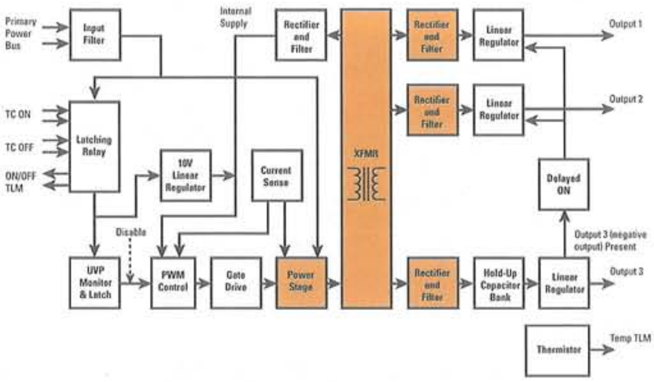

Figure 1: Example of the MB Platform assembly

The design topology allows different bus voltages to be accommodated using simple component changes in the primary section.

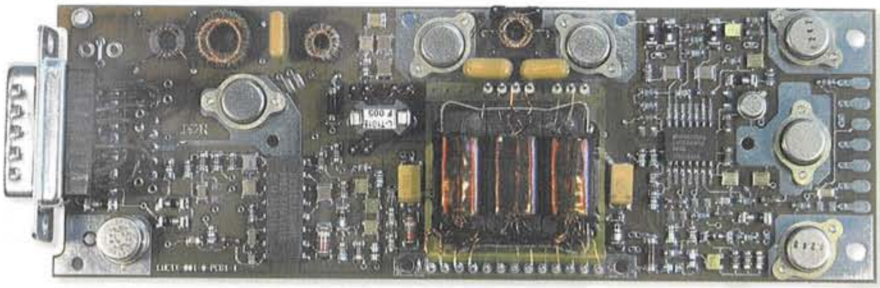

Figure 2: Design Topology for both the MA and MB platform

The platform includes TC/TLM design that can be readily adapted to most major satellite interface requirements. There is also a hold-up capacitor bank and electrical circuitry to ensure proper turn-on and turn-off timing among the outputs, and to provide the critical biasing sequence for GaAs FET devices commonly used for RF power amplifiers.

There are two standard assembly outlines: the MA platform for output power up to 5W, and the MB platform with a slightly larger outline for output power up to 15W. Open-board PCB-style construction supports adapting and changing of designs as needed. Figure 1 shows an example of the MB platform assembly.

Design simulation tools and design analysis templates are also available, to help designers quickly and accurately predict performance and design trade-offs, and evaluate design changes 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 the programme schedule.

Figure 2 illustrates the design topology for both the MA and MB platforms. The differences between the two designs are concerned with the primary power stage, power transformer and output rectification scheme, and are highlighted as shaded blocks.

Outputs 1 and 2 are typically designated as positive outputs. Each output begins turn-on only after Output 3 (negative output) reaches its regulation band. 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 a safe-level nearing 0V during a power-down sequence.

While triple-output designs are common for most applications, the platform can easily be configured to accommodate any number of outputs – limited only by the total combined output power requirements. The outputs can also support a broad voltage/current range.

Design Topology

Both the MA and MB designs include two voltage regulation stages, one in the primary and one in the secondary. Regulation in the primary uses current-mode control topology to maximise efficiency. This 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. Upon power-up, an internal 10V linear regulator governs all of the primary circuitry, including PWM controller and gate driver. The internal 10V supply takes over all biasing responsibility after regulation is achieved.

The primary input circuitry is galvanically isolated from the secondary output via a power transformer. Secondary voltages of the transformer are stepped down, rectified and filtered to feed downstream output regulators. Independent linear voltage regulators regulate all outputs, and have inherently high noise and regulation performance. The use of discrete components with a bipolar transistor as a pass element minimises voltage headroom and maximises efficiency. The regulator circuit is a proprietary design that has been used successfully for many design applications. Extremely low output noise and high conducted susceptibility (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 ageing design analysis.

5W and 15W Designs

While both the MA and MB platforms use the same basic design topology, there are some

Parameter	Performance
Electrical	
Input DC-bus voltage	28V unregulated; 50V, 70V, 100V regulated
Protection mechanisms	Input under-voltage protection, overload and short-circuit protection
No-load operation	No-load operation will not cause excessive over voltage or damage
Efficiency	65 to 75% depending on input DC bus and output voltage
EMC - Conducted emission on output	<1 mVrms, frequency domain of 100Hz – 50 MHz
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 susceptibility	>90 dB for Iout >500 mA >100 dB for Iout ≤ 500 mA. Primary power sine wave injection of 2 Vp-p, 100 Hz – 50 MHz.
Lifetime	15 years minimum in orbit 18 years design life time for ageing
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
Mechanical & environmental properties	
Temperature	Acceptance: -20°C to +75°C Qualification: -25°C to +85°C Cold Start: -40°C Non-Operating: -40°C to +85°C
Mass	MA: 75 grams max. MB: 130 grams max.
Vibration	Meets typical launch requirements
Shock	Meets typical launch requirements

Table 1: Key generic performance for MA and MB converter design

differences in the power train designs. The 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 to minimise component count and size.

To support output power requirements above 5V, the MB platform incorporates a patented Hy-bridge rectifier topology and integrated magnetic, in conjunction with a two-switch half-bridge power stage to maximise 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. Both the single-switch flyback and two-switch half-bridge can easily accommodate a wide range of input voltages.

Table 1 summarises key generic performance parameters for MA and MB converter designs.

Input Filter

The Mx platform also includes an input filter design that yields very low reflected line noise and is able to satisfy EMI/EMC requirements of most major satellite power buses. While the design will change to accommodate different input bus voltages, changing the filter components has very little or no impact on the assembly layouts.

As far as provisions for telemetry are concerned, the TC/TLM interface is designed to accommodate a standard high-level pulse command. A latching relay provides the necessary isolation. The telemetry ON/OFF status is bi-level, and 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.

Mechanical Design, Assembly Outlines and Cooling

The MA and MB assembly outline designs take into account all the changes in component footprints due to the deviations in input and output requirements, so that the established PCB layouts and dimensions can normally be maintained for most design applications.

Milestone Event	Time after receipt of order
Kick-Off Meeting	1 week
Initial design (ICD, I/F, etc.)	1 month
Detailed Design	2 months
Preliminary Design Review (PDR)	2½ months
Internal Elegant Breadboard (EBB)	3 months
EM/EQM Delivery	5½ months
Critical Design Review (CDR)	6 months
Manufacturing and Test Readiness Review	7 months
FM delivery, 1st Unit	8 months

Table 2: Typical program-milestone schedule for an Mx converter

The assemblies are open-board PCB-style construction using a combination of thru-hole and surface mount components. MA outline dimensions are 85.0mm length x 61.0mm width x 19.5mm height, with corresponding dimensions of 152.4mm x 50.8mm x 18.0mm for the MB assembly. The electrical interface is achieved via solderable terminals for the MA series and a combination of sub-D connector and solderable terminals for the MB series. On-board mounting holes allow the assembly to be fastened to host equipment or to a higher level assembly. These holes are also used to conduct heat from the assembly, to help meet cooling requirements.

Platform-based project schedule

The Mx platform allows engineers to reach the Elegant Breadboard (EBB) stage for engineering evaluations within three months. Delivery of FM hardware with complete SDRL items can be expected in about eight months. Table 2 shows a typical program-milestone schedule for an Mx converter.

Conclusion

The conventional approach to designing and building DC-DC converters for a new satellite can take many months; yet these items make up only a small part of the overall project.

A platform for space-grade power converter design has been introduced, including a standardised board layout and cooling provision, simplified component selection and easy completion of supporting documentation to ease compliance activities. Crucially, the platform also provides the flexibility that designers need to satisfy proprietary specifications for the satellite power bus and converter input/output characteristics.

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