High Power Density Electronic Power Conditioner for Airborne Transmitter

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Abstract: *The modern airborne transmitters for RF imaging, demand compact size and high RF output power. Miniature Klystrons offer higher efficiency, low voltage operation and compact size as compared to Traveling Wave Tubes (TWT) delivering similar output power within narrow bandwidth. Development of a high power density Electronic Power Conditioner (EPC) described in this paper complements a miniature klystron for delivering low phase-noise in the RF output, achieved with stringent control over the regulation, stability and ripple in the high voltage output for the anode voltage. High efficiency of the EPC allows operation of the transmitter for limited time without cooling.*

Keywords: Klystron; RF Transmitter; High power density EPC

Introduction

The EPC is expected to power the operation of Klystron for a duration not exceeding 60 seconds, without any cooling. The Klystron has a grid for the beam control for facilitating pulsed operation, with a maximum duty limited to 30%. The EPC delivers power to the Klystron for the heater, modulator and the cathode-collector electrodes. The Klystron has a single-stage collector which is at the same potential as the body. The EPC has a heater unit which is designed to operate in dual mode on demand. The Boost filament mode allows the heater to warm-up quickly for emergencies. Fig. 1, shows the block schematic for the EPC.

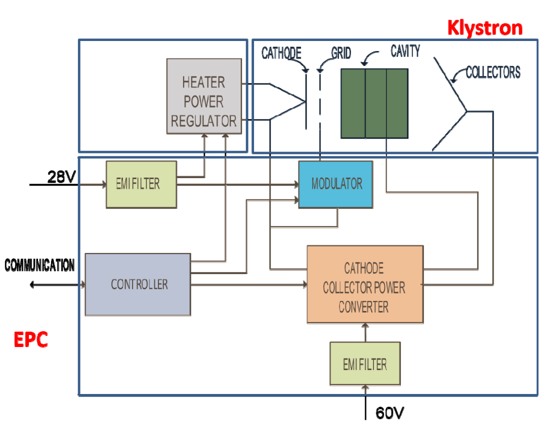

Fig 1. Block Schematic of EPC

The performance features of the EPC are tabulated in Table. I

Table 1: Performance features of EPC

✓	Weight	<500g
✓	Volume	< 17 in3
✓	Power Conversion Density	> 40W/in3
✓	HV Power delivery demand	650W
✓	Efficiency	>90%
✓	Spurious	<-60dBc
✓	Phase Noise @5kHz away	<-95dBc/Hz

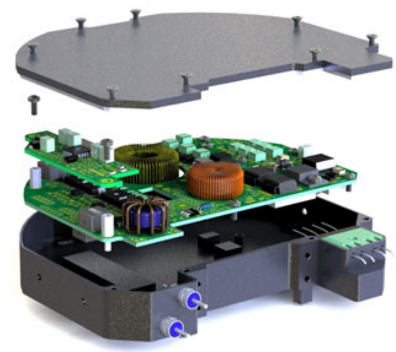

Fig 2. The 3D-Model of the proposed EPC

Epc module description

The EPC has several subsystems for achieving desired functions of powering the accelerating anode, heater and the grid modulator. The following paragraphs describe them in detail.

Table 2: Brief specification of Epc

Module	Parameters	Typical	Unit
Prime Power 1	Steady state voltage	60	Vdc
	Power delivery capacity	600	W
Prime Power 2	Steady-state voltage	28	Vdc
	Power delivery capacity	50	W
Cathode-Collector power converter	Voltage	3	kVdc
	Body interception/Collector current	600	mA
	Regulation	0.1	%
	Ripple	0.01	%
	Stored energy	1	J
Heater Power converter	Dual Mode Heater operation	4 or 5	V
	Normal Heater Current	2 to 6	A
Total HV output power		650	W

Cathode /Collector High Voltage Power converter: The HV power converter has to run on prime power 1, 60V (nominal) DC bus sagging to 54V in the worst-case and on the higher side up to 66V from the onboard thermal-battery. The Cathode-collector power converter is required to provide an estimated 650W of conditioned power for the Klystron at the cathode potential of up to 3kV.

A load resonant, zero voltage switched H-bridge topology is chosen for the Cathode/collector power supplies due to its inherent short-circuit protection feature. The converter works at 320 kHz switching frequency to optimize the size and efficiency. PM-PWM technique is chosen for achieving the regulation. The multi-tapped HV transformer outputs are rectified and stacked to generate the required high voltages for the cathode and collector electrodes of the Klystron. Voltage-tripler circuits are employed at the HV outputs from the transformer to bring down the turns ratio and consequently the volume of the transformer. A Nanocrystalline toroidal transformer has been used by utilizing the full window area and flux density.

The closed-loop bandwidth is optimized to achieve stability in the high voltage for achieving stringent phase-noise requirement in the RF output. The high voltage output is filtered with passive filters for achieving spurious better than -60dBc.

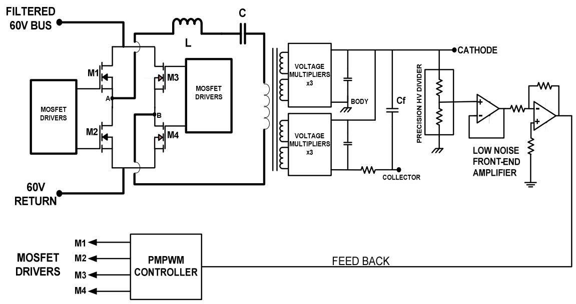

Fig. 3. Cathode Converter topology

The Grid Modulator: Two MOSFETs are configured in totem-pole mode with beam-OFF and beam-ON voltage levels fed to the lower MOSFET source and top MOSFET's drain respectively as shown in the block schematic in Fig. 4. The modulator and the heater are powered from the prime power 21. The Modulator performance requirements are summarized in Table-III below.

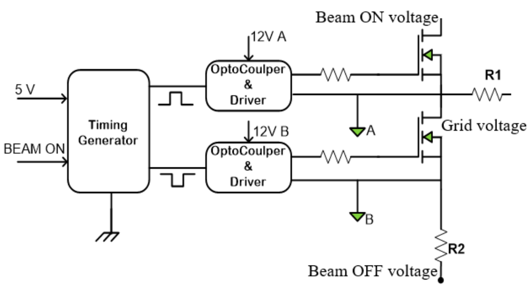

Fig 4. Block schematic of the Modulator unit

Table 3. Brief specification of Grid Modulator

Function	Parameter	Typical	unit
Beam Control	Klystron beam cut-off bias, Negative w.r.t. Cathode	-600	V
	Klystron Beam ON bias	0-90	V
	Peak Grid Interception current	10	mA
	The operating pulse repetition frequency	10-600	kHz
	Pulse width	0.3-5	µS
	Duty cycle	0-40	%
	Throughput delay	100	nS

The regulated Beam ON voltage and Beam OFF voltage are tapped from the transformer secondary of bias generator converter. Multiple tapings are used to generate pulse top voltage as desired in steps of 15V and a linear regulator for fine-tuning.

Silicon carbide MOSFETs (SiC) are employed in the modulator, for minimizing the output capacitance for high voltage pulsed operation at 600 kHz, which enables dissipation as low as 50mW/kHz for the desired voltage swing. The MOSFETs floating at the cathode potential are cooled by employing AlN (Alumina) wafers placed below the MOSFETs and mounted on the chassis. The drives to the floating MOSFETs are transported through optical-isolators for desired operation at the cathode potential.

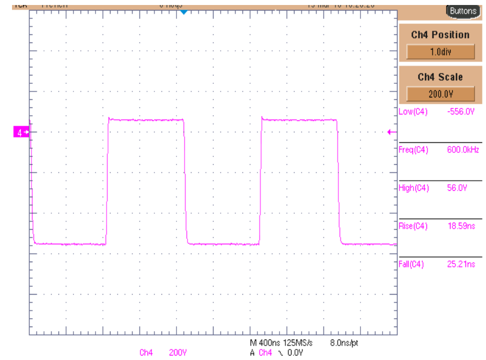

Fig. 5. 600 kHz Grid Modulator Switching

Filament Supply: A buck converter with optically isolated feedback control is employed for controlling the filament voltage. The filament power supply is capable of operating in dual-mode, namely; normal heating mode and boost-mode. In boost-mode operation, higher voltage is provided for an appropriate duration to make cathode ready for quick emission requirements. An input command chooses the required mode of operation. The block schematic is given in Fig. 6

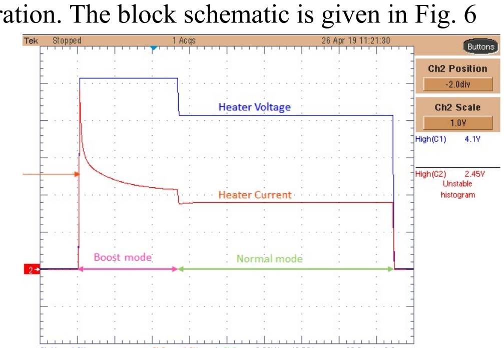

Fig. 6. Dual Mode Heater configuration

EMI Filter: The conducted EMI of the transmitter is measured at full duty and the cut-off frequencies of the common-mode and differential-mode filter are accordingly finalized for compliance to MIL-STD-461E EMI/EMC requirement.

Conclusion

The paper described the development of a compact airborne EPC for powering a miniature klystron for delivering low phase-noise, low spurious RF output for an RF imaging airborne application.

References

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