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Power processing unit for hall-effect thrusters on "Meteor-M №3 spacecraft"

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Abstract. The development results of power processing unit (PPU-M) for hall-effect thrusters on «Meteor-M №3» spacecraft are considered. The structure, weight, dimensions and main technical characteristics of the system in the paper are presented. The work peculiarity of the system is unstable input voltage of both power bus and control bus that increases the ripple voltages and currents at the input and the output and causes the additional requirements to the circuit design. A comparative analysis of the system characteristics and European analogs was carried out, and then a conclusion on the basis of available data that the characteristics of the system are not inferior to European analogs was made.

1 Introduction

Power processing unit provides the required modes of two SPT-100 (Stationary Plasma Thruster) thrusters installed on board of «Meteor-M №3» spacecraft and designed to station-keeping during the whole lifetime (7 years) and then to inject into Graveyard orbit. PPU-M is suitable for operation in open space and provides the required power supply modes for the loads shown in Table 1.

Table 1. Loads of PPU-M.

Load type	SPT-100	Thruster valves	Xenon storage bank valves	Pyrovalves	Xenon flow regulators
Quantity, pcs	2	12	6	2	2

2 PPU-M Design

PPU-M is designed as a monoblock and has two channels of power supply, each of which supplies the power for one thruster (Figure 1).

Structurally, PPU-M consists of 14 modules installed on a common base, connected by a bus and closed by a protective cover. Figure 2 shows a power supply circuit of one SPT-100 thruster type.

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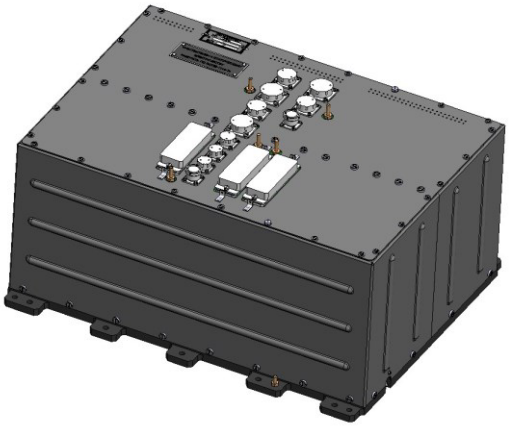

Figure 1. PPU-M mechanical design.

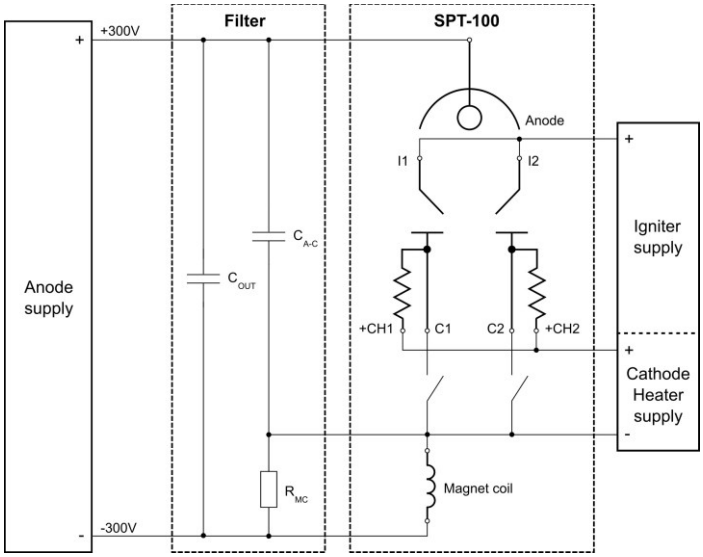

Figure 2. Power supply circuit of SPT-100: CH – Cathode Heater; C – Cathode; I – Ignition Electrode; $C_{A\text{-}C}$ – anode-cathode capacitor; C_{OUT} – output capacitor; R_{MC} – magnetic coils ballast resistor.

3 PPU-M Specifications

PPU-M work peculiarity is unstable input voltage: in the power bus it varies in the range of 46 - 65 V, and the control bus in the range of 24 - 34 V. Pulsed power consumption from input sources and as a result increasing of their ripple currents and voltages are caused by this fact. A throttle is installed and value of anode supply input filter capacitor is increased to reduce them. The value of C_{OUT} capacitor is increased to reduce the voltage ripple in the anode circuit. The value of $C_{A\text{-}K}$ capacitor will be determined in the process of thruster connecting tests.

The power supply circuit of magnetic coils for SPT-100 is worked out using discharge current that eliminates additional source and reduces the weight of the device. For the same purpose the original cathodes circuit switching scheme is used, that allows switching cathode heater, cathode and the ignition electrode circuit using only one key.

In addition to the power supply sources, PPU-M has a built-in filter for protection against anode, cathode and ignition electrode circuit static electricity.

Main technical characteristics of PPU-M are given in Table 2.

Currently laboratory PPU-M sample is manufactured and developmental testing is being completed.

Table 2. Main characteristics of PPU-M.

Parameter	Value	Note
Discharge voltage, V	300±15	DC
Discharge current, A	4,5±0,1	In a start mode up to 7 A for 2 - 4 sec
Cathode heater current, A	12,0±0,5	0,2 Ohm < R_{CH} < 0,7 Ohm
Xenon flow regulators current, A	1,5 – 1,75	Preparation mode
	0; 3,8±0,2	Operating mode
Ignition pulses voltage, V	290 – 350	R_{IE} = 10±1 kOhm; f = 145±15 Hz; t_I = 70 – 140 mks
	20 – 40	R_{IE} = 5,0±0,5 Ohm; f = 145±15 Hz; t_I = 70 – 140 mks
Thruster valves voltage, V	22,3 – 32,7	Switch-on mode
	8 – 13	Hold mode
Xenon storage bank valves voltage, V	22,3 – 32,7	Switch-on mode
	8 – 13	Hold mode
Pyrovalves current, A	3 – 5	0,8 Ohm < R_{PV} < 1,2 Ohm
	0,005 – 0,015	Flow mode
Power bus voltage, V	46,9 – 65,3	Power consumption in operating mode less than 1500 W
Control bus voltage, V	24 – 34	Power consumption less than 80 W
Command quantity, pcs	17	Single commands
The number of telemetry channels, pcs	8	Analog, 0 V < U_{TM} < 5 V
	8	Signal
Reliability	0,999	Active lifetime is 7 years long; operating time is 1000 hours long
Weight, kg	17	

4 Comparative analyses

Existing analogues characteristics analysis was performed in the development phase. Main results are shown in Table 3.

The nearby analogue of the PPU-M is PPU Mk1 for Stentor spacecraft [1] because both of them operate with two thrusters type SPT-100. A significant difference in the weight of these PPUs is due to the principally different structure of design. PPU Mk1 for Stentor spacecraft contains one power supply channel and one switch module for two thrusters [2], a single failure of any element results in failure of the whole system. Only «cold» redundancy using two PPU on board is operated in this spacecraft.

In addition, unlike the PPU for Stentor and Smart-1 spacecraft, powered by a stabilized [3] power bus 50 V, in PPU-M the power supply is unstabilized (24 –34 and 46 – 65) that includes a built-in PPU stabilizer. Also the PPU-M includes a built-in filter for protect against electrostatic discharges, which is submitted as a separate and independent unit of the propulsion system in European PPU.

Table 3. Main specifications of several domestic and foreign PPU-M for thrusters SPT-100.

Name of system	Start of operation	Thruster		Weight of PPU, kg	Power supply bus, W	Anode supply		Cathode heater current I_{CH}, A
		Type	Quantity			U_A, V	P_A, kW	
PPU - 2EA (SIC "Polyus")	2013	SPT-100	8	27,1	27, 100	300	1,4	12 (DC)
PPU-M (SIC "Polyus")	2015	SPT-100	2	17	24 – 34; 46,9 – 65,3	300	1,4	12 (DC)
PPU Mk1 for Stentor spacecraft	2002	SPT-100 or PPS-1350	2	10,4	100 or 50	300 or 350	1,6	14 (DC)
PPU Mk1 for Smart-1 spacecraft	2003	PPS1350-G	1	10,9	50	175 – 350	0,306 –1,225	No data

Based on the above it can be concluded that the build structures of PPU-M and PPU (Stentor) are significantly different, that greatly complicates the identification of their specific characteristics. To ensure a high level of reliability for PPU it is required to install a redundant unit. The vast majority of foreign PPU-M analogues have a remote filter unit, whose weight is not considered.

5 Conclusion

Designed PPU-M ensures reliable operation of two SPT-100 type thrusters as part of «Meteor-M №3» spacecraft in open space with unstable input voltage. For functional and specific weight and size characteristics PPU-M is superior to foreign analogs due to the original circuit switching cathodes and monoblock design.

References

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