Power Efficient Pulsed Plasma Thruster with Precise Control of High Voltage Generation

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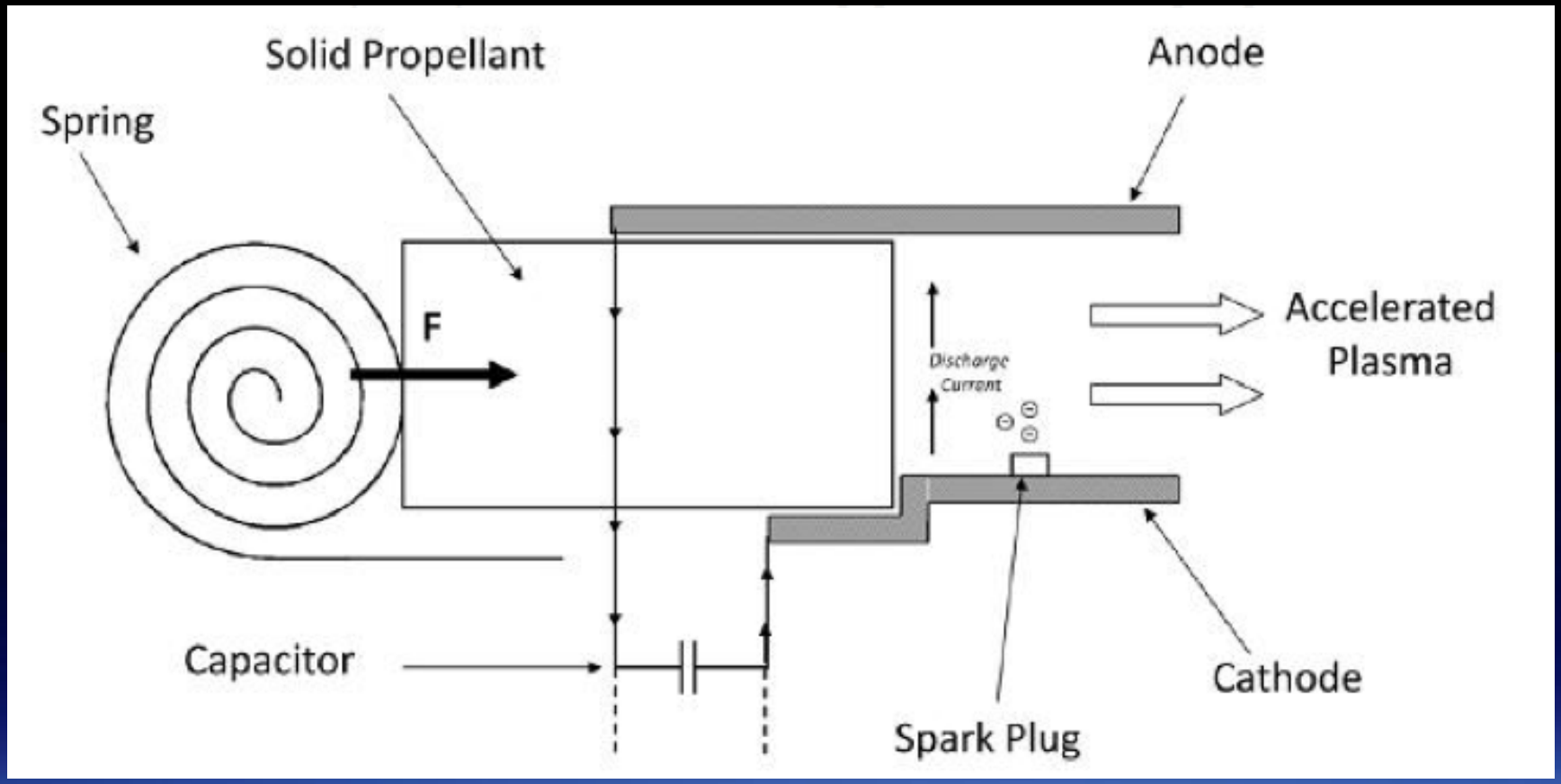
Introduction (I)

- Pulsed Plasma Thrusters (PPTs) are high-specific-impulse, low-power electric thrusters.
- Teflon used as propellant. Ablation of Teflon produces Plasma.
- High-energy storage element (some Joules). Voltage of 1-2kV,
- Igniter allows main discharge (5-10kV).
- Plasma accelerated by Lorentz force: Thrust!
- No pressure vessel to keep the launch provider happy.

Introduction (II)



Introduction (III)

- Clyde Space Ltd and Mars Space Ltd have been working together on the development of different types of PPTs for both CubeSats and Nanosatellites.
- Experience and different test campaigns allow the improvement and development of new topologies.

Need for Thrust

- Lifetime of LEO Nanosatellites and CubeSats limited by natural de-orbiting.
- Flight Formation.
- Attitude Control.
- Low-thrust maneuvers .

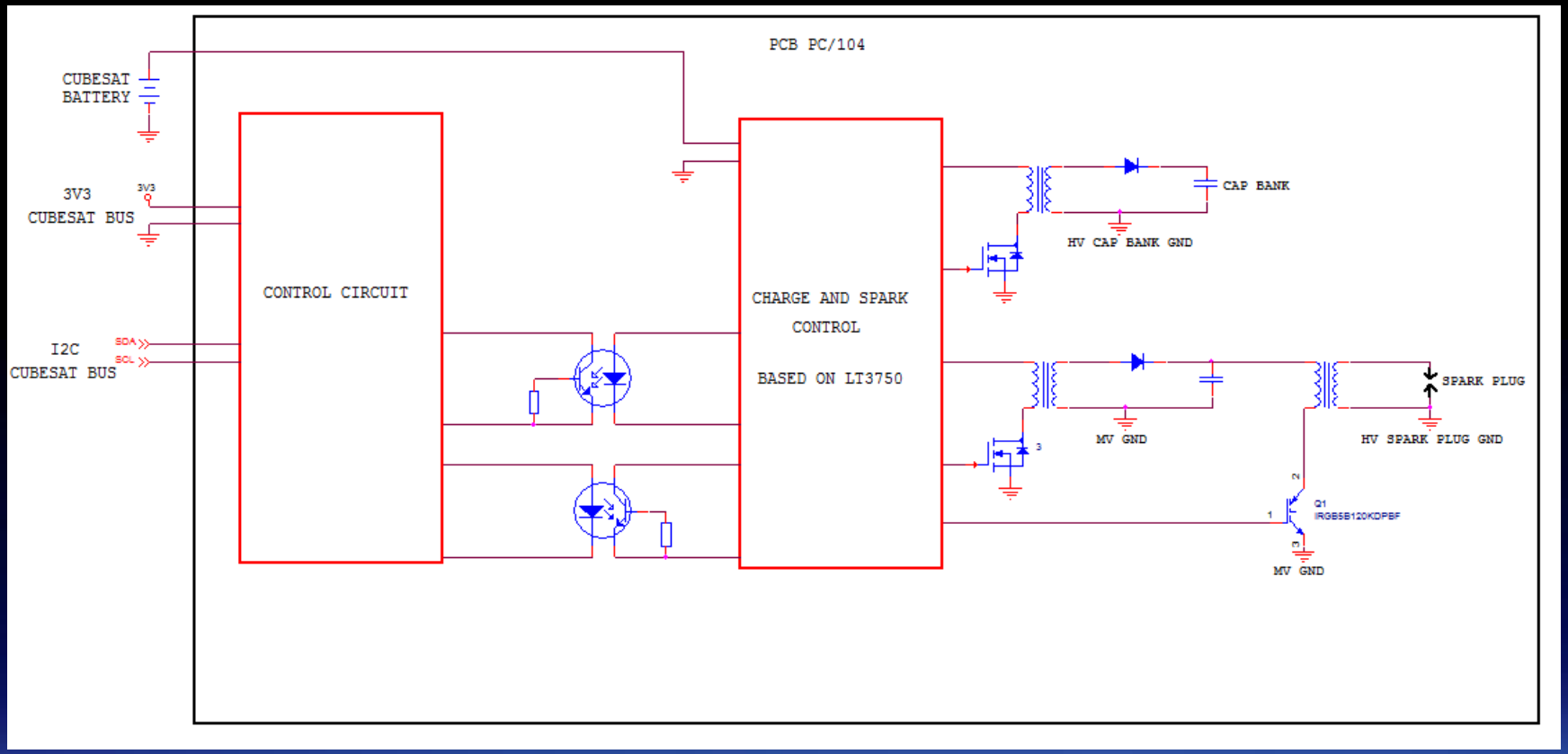
Requirements and Constraints

- Limited space in the satellite: Our target is to fit within a 0.3U enclosure.
- Limited power allocated: Low power consumption.
- Precise and repeatable generation of voltages.
- Low noise – conducted and emitted.
- Accurate control of the firing process.

New Topology (I)

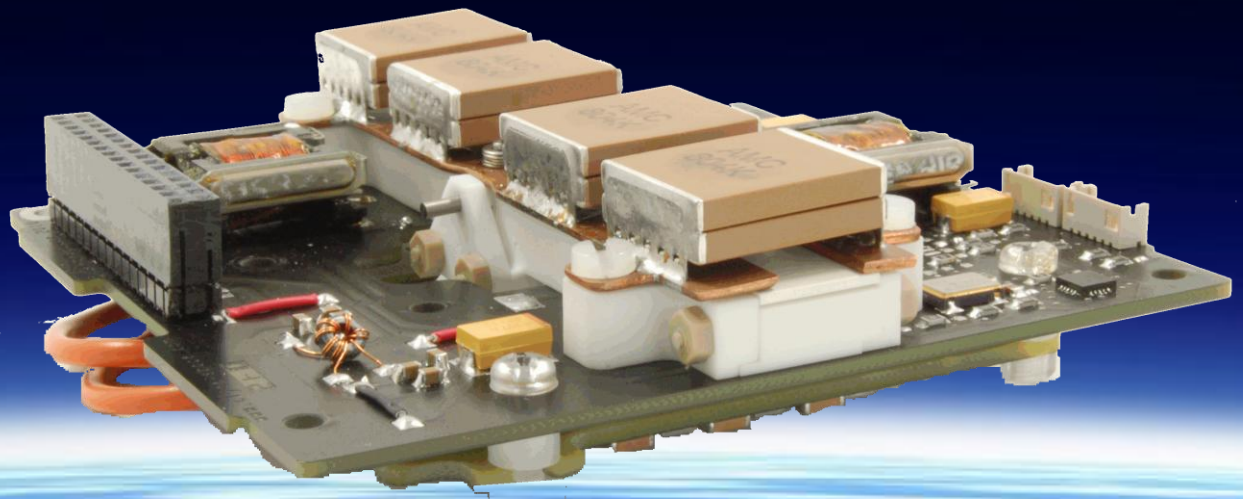
- Analog circuit for high generation of high voltages (main discharge capacitors & spark plug).
- Digital circuit to interface with the rest of the satellite and the analog circuit (MCU, Communications, Command Signals).
- Galvanic isolation between both digital and analog circuits.

New Topology (II)



Main Discharge Capacitors

- Circuit uses a Flyback topology:
  - Inherent galvanic isolation between low (6V) and high voltages (1-2kV).
  - Precise control of the level of charge/energy of the main discharge capacitors.



Spark Plug (I)

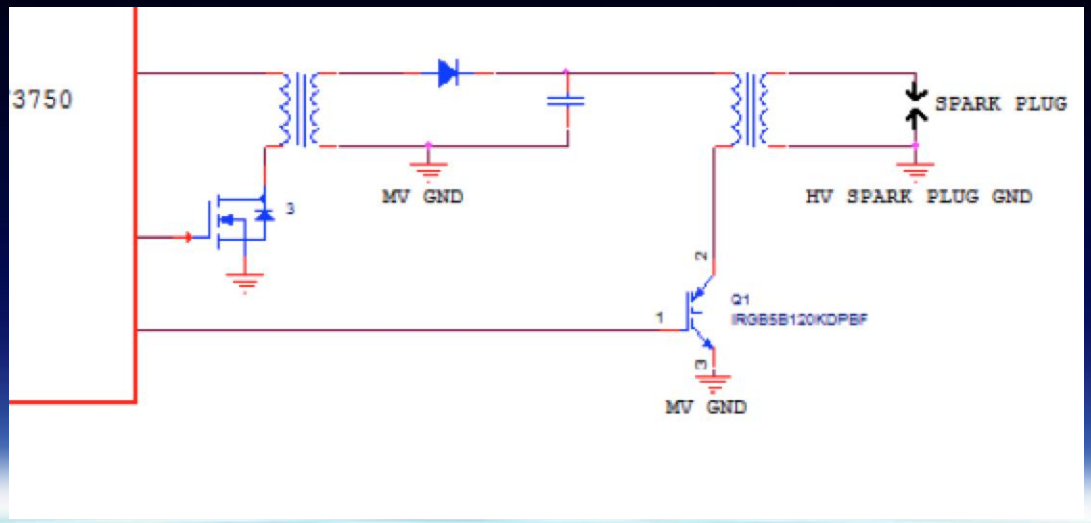
- Other circuits use voltage multipliers topologies which produce a burst of pulses.
- Our PPT uses a Flyback converter:
  - Single pulse is accurately generated.
  - Power consumption reduced by the use of a two stages circuit.
  - Repeatability of the pulse generation.
  - 5-10kV output

Spark Plug Circuit (II)

- Double stage circuit:
  - Fist stage: Flyback converter charges a capacitor.
  - Second stage: energy of the capacitor dumped into the primary winding of a high voltage transformer.

Result:

High Voltage generated on the Spark Plug



Digital Interface

- Interfaces with the satellite On Board Computer.
- Controls the charge of the bank of capacitors and firing sequence.
- Use of RS422 or I^2C protocols.

Results

- The electronics have been tested with two different discharge chambers:
  - For Nanosatellites
  - For CubeSats
- Tests have been carried out in a vacuum chamber simulating real LEO conditions.
- Thrusters have undergone 1 million shots.
- Transformers designed and potted at Clyde Space.

Characteristics of the PPT for CubeSats

- Specific Impulse = 600s
- Total Impulse: 44Ns (dV of 11m/s of a 3U (4Kg)
- Impulse Bit = 40 uNs (thrust of 40uN if the PPT is fired at 1Hz)
- Propellant stored on board = 7g
- Voltage for digital interface = CubeSat 3V3 Bus
- Voltage for high voltage generation = battery bus.
- Final version housed in enclosure.
- Available to buy now for $17,250.

Thank you for your interest!

Any questions?