



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

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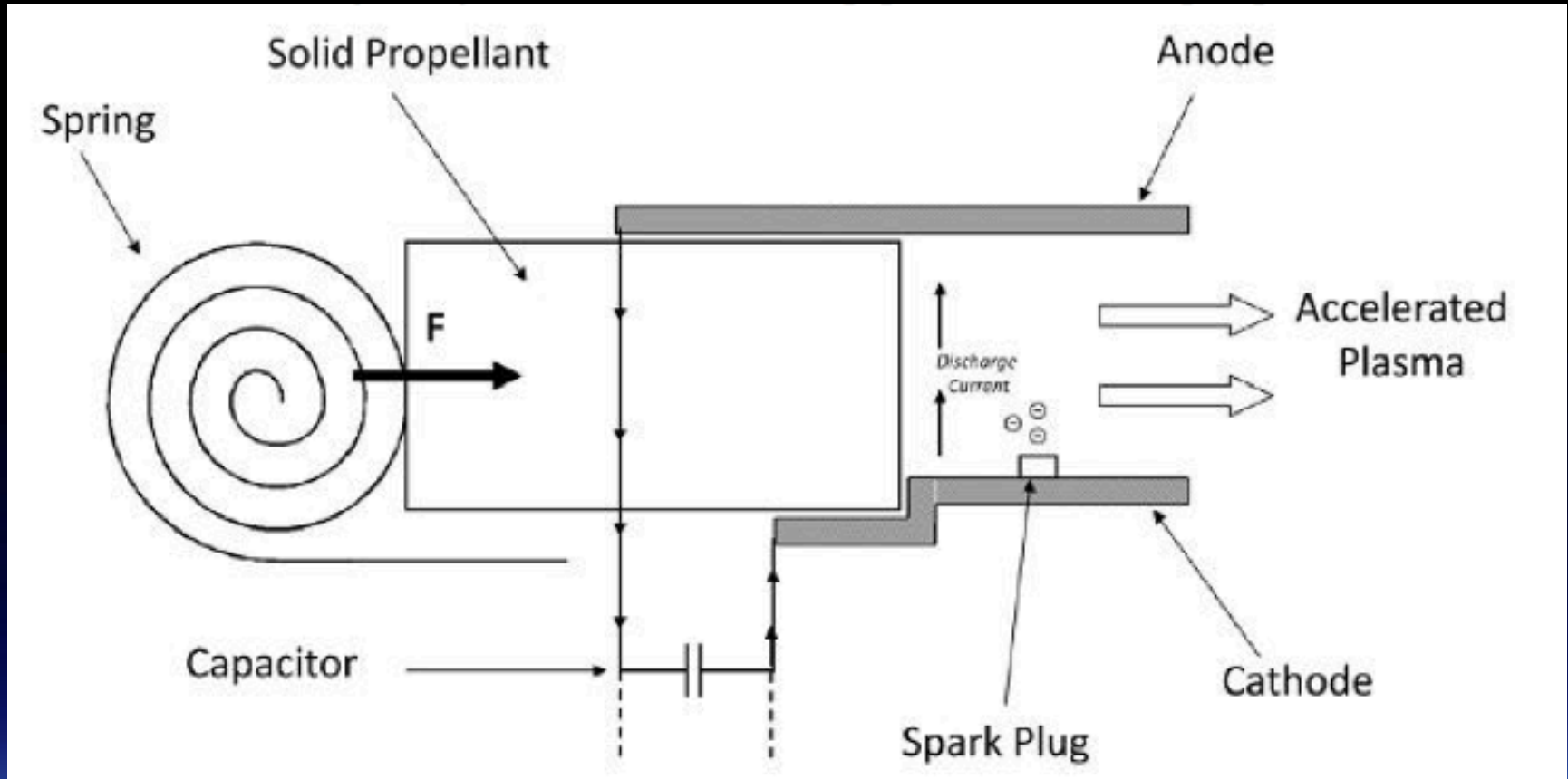
Presented by Craig Clark

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



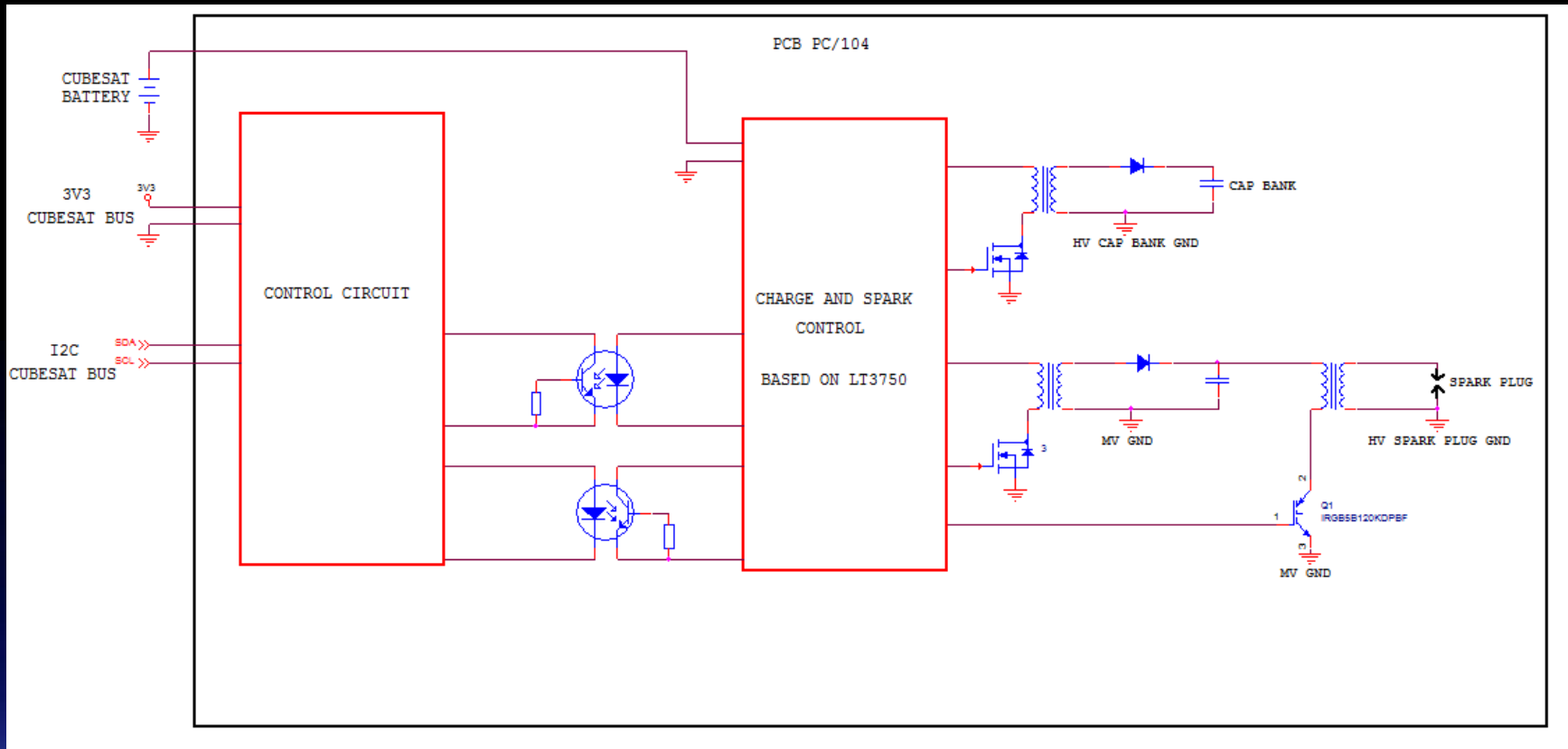
- Limited space in the satellite: Our target is to fit within a 0.3U enclosure.
- Limited power allocated: Low power consumption.
- Precise and repeatable generation of voltages.
- Low noise – conducted and emitted.
- Accurate control of the firing process.

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.

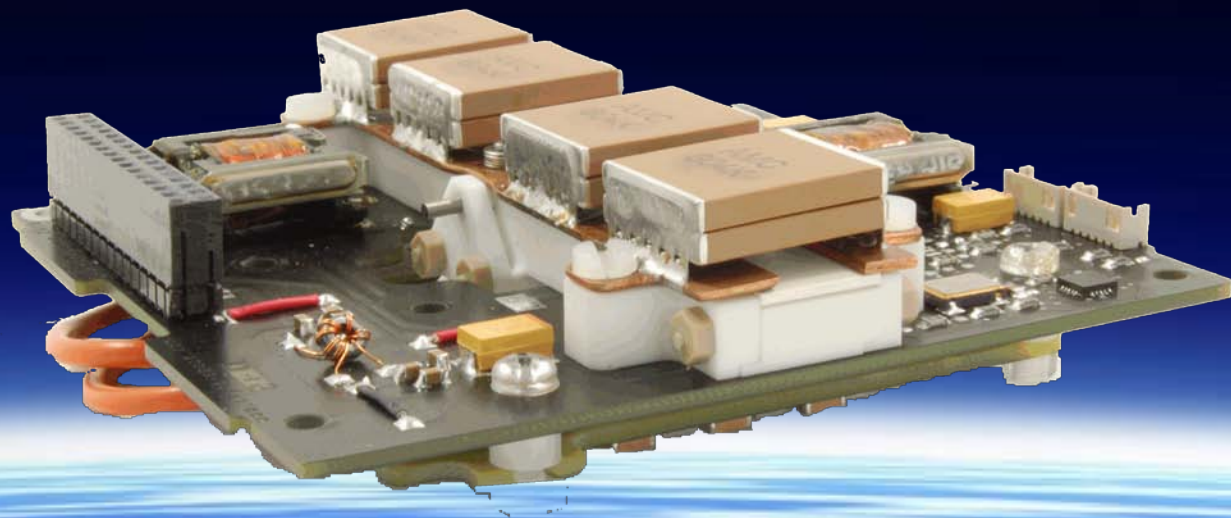
New Topology (II)



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 multiplier 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



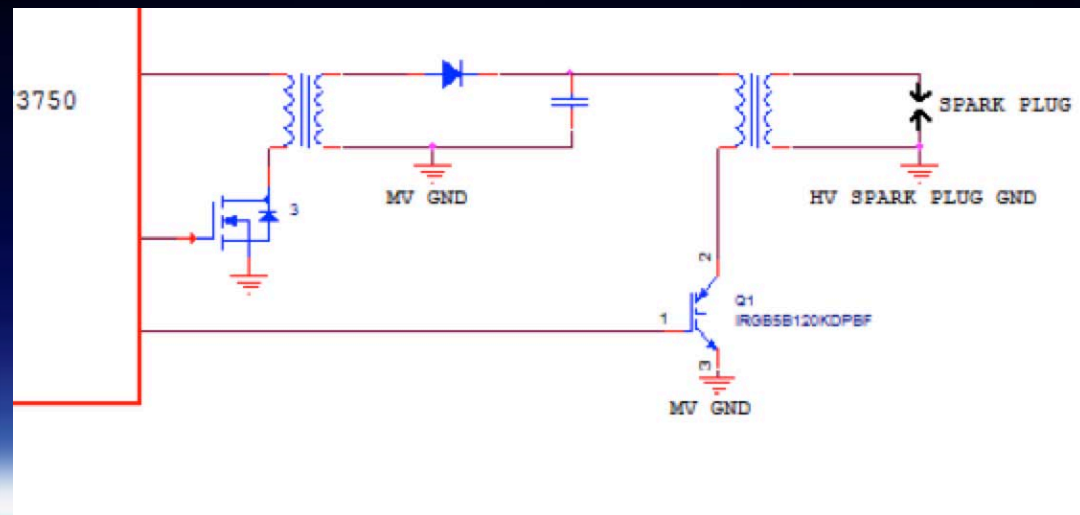
Spark Plug Circuit (II)



- Double stage circuit:
 - First 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 I²C 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?

