# Pulsed Operation of an Ion Accelerator

## Thrust can be varied more rapidly and with greater precision and range.

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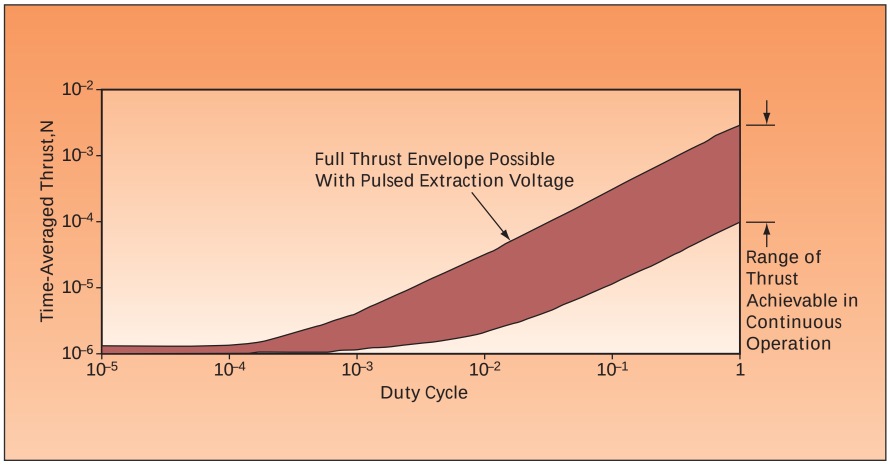
Electronic circuitry has been devised to enable operation of an ion accelerator in either a continuous mode or a high-peak-power, low-average-power pulsed mode. In the original intended application, the ion accelerator would be used as a spacecraft thruster and the pulse mode would serve to generate small increments of impulse for precise control of trajectories and attitude. On Earth, pulsed operation of ion accelerators could be utilized to effect precise control of output ion fluxes in plasma and ion-beam apparatuses commonly used in the semiconductor processing industry.

It has been conventional practice to operate an ion thruster in a continuous mode in which (1) the thrust or ion flux is regulated by adjustment of the discharge current and/or throttling of the gas from which the ions are formed and (2) the extraction voltage (typically of the order of a kilovolt) is maintained constant or adjusted over a limited range. These techniques produce only a limited range of the average thrust and the control subsystem needed for upstream regulation of thrust or ion flux is necessarily somewhat complex.

The present electronic drive circuitry generates the extraction voltage in pulses. Pulse-width modulation can affect rapid, fine control of time-averaged impulse or ion flux down to a minimum level much lower than that achievable in continuous operation (see figure). Since there is little or no need for upstream regulation to affect fine control, the upstream operational parameters can be held constant and, therefore, much of the control subsystem heretofore needed for upstream regulation can be simplified.




**Time-Averaged Thrust** was calculated theoretically for a representative ion thruster operating in continuous and pulse modes. A minimum average thrust much lower than that attainable in continuous operation (about 1 μN, below which the thrust due to ion flux is comparable to the flow of the propellant gas without ionization) would be achieved by pulsing at a low duty cycle.

The challenge in designing the circuitry was to provide rapid turn-on and turn-off of the high extraction voltage in the presence of thruster and circuit capacitances, while preventing undesired voltage and current transients. The approach taken to meet this challenge was to utilize a low-voltage pulsed waveform from a signal generator to command a pulse-circuit to generate a corresponding high-voltage waveform, and to enable rapid bleeding of charge from the high-voltage side of the thruster capacitance to thruster common (that is, thruster ground) when the high-voltage pulse is turned off. The signal generator drives an operational amplifier that triggers a transistor, the output of which causes the simultaneous opening and closing of the various thruster voltage lines. One of the lines contains an appropriately sized resistor that serves to drain the thruster capacitance to achieve rapid fall of the voltage and current, and thereby the thrust, which allows very precise thrust knowledge and minimizes thruster erosion, while preventing ground loops.

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