A Bipolar Microsecond Pulser for Electroporation and Cancer Therapies

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EAGLE HARBOR TECHNOLOGIES

Introduction

Emerging biomedical therapies that use electroporation and other electrode-driving techniques require new medical pulsed-power systems. In electroporation, electric fields are applied to cells to increase the permeability of the cell membrane. Chimeric antigen receptors (CAR) T-cell-based therapeutics is a growing electroporation application that requires complex pulse and burst patterns with high-voltage, bipolar pulses.

To address the growing biomedical market demand, Eagle Harbor Technologies, Inc. (EHT) developed a programmable, bipolar microsecond pulse generator. This pulse generator produces ±3 kV pulses with pulses widths from 500 ns to DC at high pulse repetition frequencies up to 100 kHz and precision burst control. An internal microcontroller combined with a graphical user interface allows the user to remotely control the pulse widths, dwell times, and burst patterns. We will present the pulser capabilities including output waveforms.

Pulser Specifications

Several companies have inquired about a highly-controllable bipolar microsecond pulsers for electroporation and other biomedical applications. The unit should incorporate a solid-state switching module with gate drive circuitry, low-voltage power, control module with microcontroller, and high speed logic for interlocks and overvoltage/overcurrent protection.

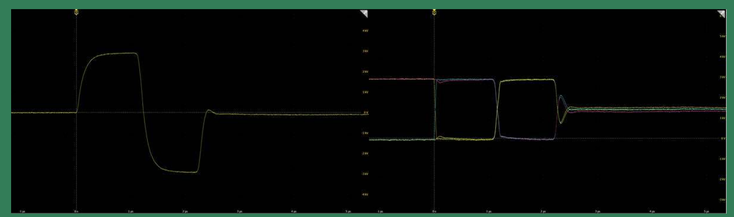
Targets Specifications:

- Charge Voltage: 0 – 3 kV
- Output Voltage: -3 kV – 3 kV (Bipolar Output)
- Output Current: 0 – 40 A
- Positive Pulse Width: 0.5 – 3 µs
- Negative Pulse Width: 0.5 – 3 µs
- Pulse-to-Pulse Dwell: 0.2 – 3 µs
- Pulse Repetition Frequency: 0.1 – 10 kHz
- Number of Pulses: 1 – 2500
- Burst Frequency: 0.1 – 1 Hz
- Internal Energy Storage: 24.5 J at 3000 V charge
- Control: LAN Control or Fiber Control
- Overcurrent Protection: Yes

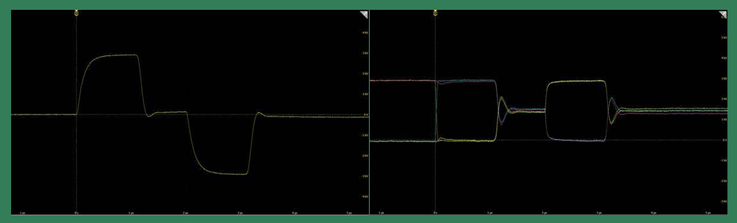
Circuit Topology

Several circuit topologies were evaluated including a half bridge and full bridge. A half bridge would allow independent control of the positive and negative voltages; however, it would require two DC power supplies and only allow operation at 1.5 kV. Ultimately, a full bridge was selected to lower costs and allow for higher voltage pulses.

Switching and Output Waveforms



Output voltage measured across a 70 Ω load (left) and Vce measurements of all four switching positions (right - yellow is position 1, blue is position 2, red is position 3, green is position 4). 3 kV charge, 1 µs pulse width for both the positive and negative pulse, 100 ns dwell time between pulses.



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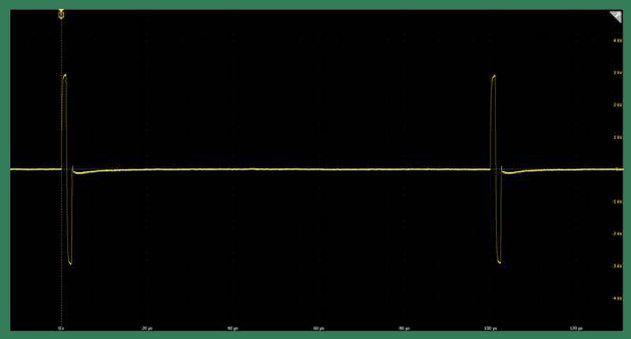
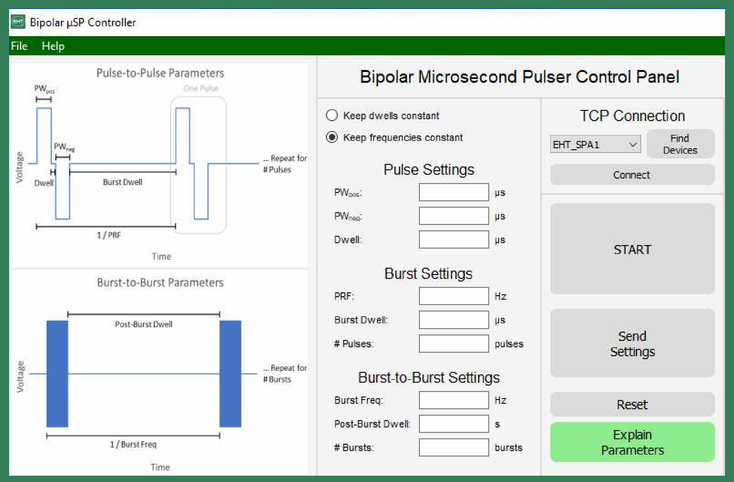


Output voltage measured across a 70 Ω load, 3 kV charge, 1 µs pulse width for both the positive and negative pulse, 100 ns dwell between pulses, two pulses at 10 kHz PRF.

Control Module

The core of the control module is a STM32H755 microcontroller. The control module uses TCP communication via the Ethernet port. The microcontroller controls the gates while preventing shoot-through conditions, takes in analog overvoltage/ overcurrent signals, and monitors an input for an external trigger.

The control software allows for a controllable pulse and burst outputs. The software generates the burst envelope based on user input. It also allows for configurable/persistent trigger and burst envelope levels.



Screenshot of graphical user interface showing pulse and burst control.

Conclusion

EHT developed a bipolar microsecond pulser for biomedical applications like electroporation and electrode driving. This pulse generator offers researchers independent control of pulse timing for precision control of power to their load.

For more information: http://www.eagleharbortech.com/