

Bipolar Microsecond Pulse Generator for Biomedical Applications

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EAGLE HARBOR TECHNOLOGIES

Introduction

Emerging biomedical therapies require new precision pulsed-power systems for electroporation and other electrode-driving techniques. In electroporation devices, electric fields are applied to cells to increase the permeability of the cell membrane. One growing application is the use of electroporation to improve chimeric antigen receptors (CAR) T-cell-based therapeutics. These applications require complex pulse and burst patterns with high-voltage, bipolar pulses.

To address this growing need within the biomedical community, Eagle Harbor Technologies, Inc. (EHT) has developed a programmable, bipolar microsecond pulse generator. This pulse generator can produce ± 3 kV pulses with pulse widths from 500 ns to DC at pulse repetition frequencies up to 1 kHz (continuous) or 100 kHz (short bursts). The pulse generator includes an internal microcontroller that allows the user independent control of the pulse widths, dwell times, and burst patterns. EHT has created a simple graphical user interface to simplify control. We will present the pulser capabilities including output waveforms.

Pulser Specifications

In the past year, several companies have inquired about a highly-controllable bipolar microsecond pulsers for electroporation and other biomedical applications. They wanted precision control of the pulse timing including

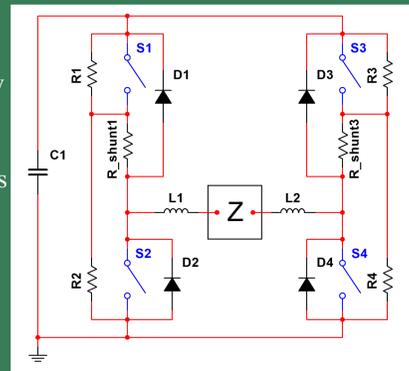
The unit should incorporate a solid-state switching module with gate drive circuitry, low-voltage power, control module with microcontroller, and high speed logic for interlocks and overvoltage/overcurrent protection.

Targets Specifications:

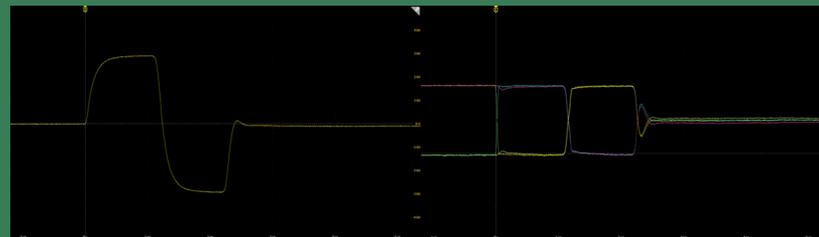
- Charge Voltage: 0 – 3 kV
- Output Voltage: -3 kV – 3 kV (Bipolar Output)
- Output Current: 0 – 40 A
- Positive Pulse Width: 0.5 – 3 μ s
- Negative Pulse Width: 0.5 – 3 μ s
- Pulse-to-Pulse Dwell: 0.2 – 3 μ s
- Pulse Repetition Frequency: 0.1 – 10 kHz
- Number of Pulses: 1 – 2500
- Burst Frequency: 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

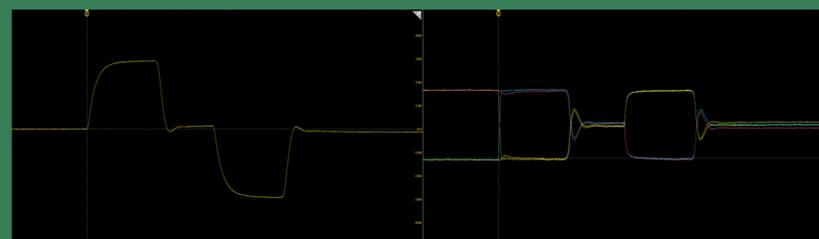
Several circuit topologies were evaluated including a half bridge and full bridge. A half bridge would allow independent control of the positive and negative voltages; however, it would require two DC power supplies and only allow operation at 1.5 kV. Ultimately, a full bridge was selected to lower costs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



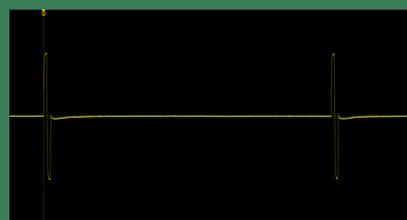
Switching and Output Waveforms



Output voltage measured across a 70 Ω load (left) and V_{ce} 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 μ s pulse width for both the positive and negative pulse, 100 ns dwell time between pulses.



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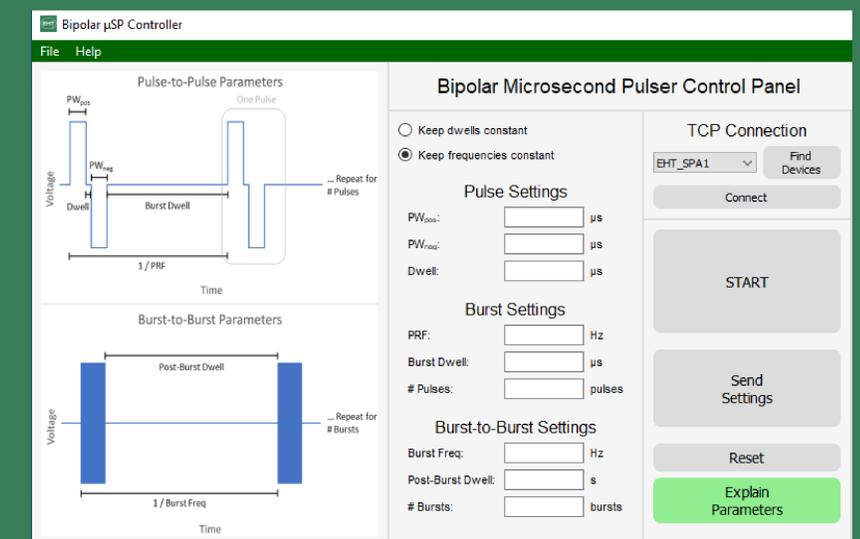
Output voltage measured across a 70 Ω load, 3 kV charge, 1 μ s pulse width for both the positive and negative pulse, 100 ns dwell between pulses, two pulses at 10 kHz PRF.

Control Module

EHT selected a STM32H755 microcontroller as the core of the bipolar microsecond pulser's control module. The control module uses TCP communication via the Ethernet port. The microcontroller controls the full-bridge topology 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.

To simplify user-control, EHT developed a custom graphical user interface that provides an intuitive way to create custom pulse/burst trains.



Screenshot of graphical user interface showing pulse and burst control.

Conclusion

EHT has developed a bipolar microsecond pulser for biomedical applications like electroporation and electrode driving. EHT developed the solid-state switching system and microcontroller-based control and timing module. This pulse generator offers researchers independent control of pulse timing for precision control of power to their load. Our engineers also developed a graphical user interface to provide a simple way to create complex pulse and burst patterns.



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