

A NEW TYPE HIGH VOLTAGE FAST RISE/FALL TIME SOLID STATE MARX PULSE MODULATOR

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Abstract

A new type of solid state Marx modulator developed by Stangenes Industries has the capability of producing high voltage pulses with fast rise and fall time at high repetition rates. In addition, it has the ability to produce dynamically flexible output amplitude and pulse width. The pulse modulator was developed for the Fermi Labs Tevatron Electron Lens Tune Compensation System. It can produce a 14kV pulse with 200-nanosecond rise time and 600-nanosecond full pulse width at a 25-kilohertz repetition rate. It has no overshoot or reverse voltage, making it ideal for beam bunch manipulation. It was designed to operate into a 200 pfd, 800-ohm load. This design permits all of the sources of power including the 1kV charging power supply to be connected at the grounded end of the pulser. A second-generation pulser is under development to operate at above 50 kHz repetition rate with an arbitrary voltage waveform and faster rise/fall time. The pulser can accommodate load arcing and incorporates built in redundancy to insure high availability. The paper delineates the unique design of the modulator and its performance.

PRESENT DESIGN LIMITATION

At present to obtain a fast rise and fall time with dynamic pulsed width and amplitude waveforms requires a “hard tube”, solid-state equivalent modulator or an induction modulator to produce the required pulse waveform at high voltage and fast rise time.

These designs have a number of issues that limit their performance and application. Hard tube modulator requires the equipment to operate at high voltage with high voltage supplies power and it is very difficult to produce a fast fall time and dynamic amplitude. The output is usefully either on or off at a fixed voltage which provide no amplitude flexibility. An induction modulator can adjust its output voltage dynamically but it has difficulty producing fast fall times and keeping its cores reset under burst mode operation. In addition, core resetting produces a reverse voltage, which may be undesirable

SOLID STATE MARX MODULATOR

The Solid State Marx modulator approach [1],[2],[3] has the advantage of lower DC voltages and multiple stages.

Its output voltage can be dynamically changed in discrete steps its can also have a fast rise and fall time to any of the discrete amplitude levels.

The classic Marx generator approach has used inductor, resistor, or transformers to supply the charging capacitors voltage and control power to the stages and spark gaps to trigger. This produced a fast rise time but a long fall time without amplitude flexibility and limited recharge or reputation rate capability. The recent improvement of high voltage IGBTs and FET switches that can turn off as well as on, have made the solid-state multistage Marx modulator practical. (Figure 1) By replacing, the charging inductor/resistors of a Marx generator with high voltage diodes and the addition of a return current switch the Marx multistage solid-state modulator can now perform better the previous designs. The use of fiber optics or RF triggering of the stages further reduces the stray capacity to ground and improve its performance.

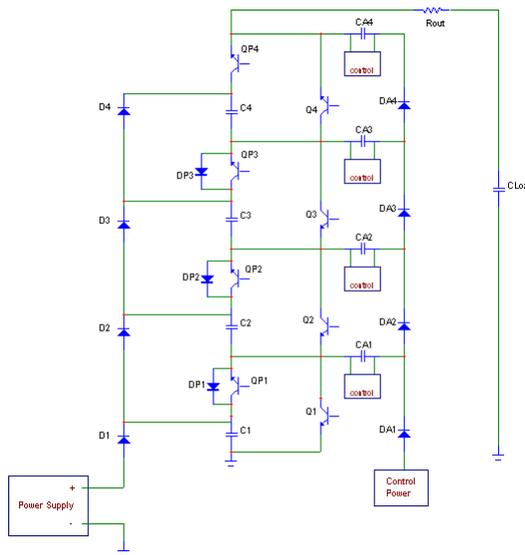


Figure 1: Stangenes Solid State Marx modulator

Operation of the Fast Stangenes modulator

The multistage modulator uses in addition to the pulsing IGBT/FET type switch a second IGBT/FET switch that is used to carry the charging current thru diodes to each stage of capacitor in parallel replacing the typical resistor, transformer, and inductor. During charging of the capacitor, the charging switch is turned on and the

capacitor is charged using a single ground reference charging power supply. With control of the return switch, individual stages can be charged if desired to different voltage if desired. (Figure 1) An additional feature is that the control power for triggering is supplies by as second diode string. The result of using the charging diodes and charging switch is that nearly all the stray capacitance is between sections not to ground. This reduced the overall capacitance required to be driven for fast rise times. Prior to the turn on of the modulators pulse discharge switches, the charging switch can be left on providing a temporary short circuit to the discharge switch allowing the load current to establish itself before the charging switch is turned off, generating a fast rise voltage.

With the discharge pulse switch on and the charge switch turned off the circuit, the previously parallel charged capacitor are placed in series producing the desired high voltage pulse. At the completion of the pulse, the discharge switch is turned off and the charging switch is again turned on, discharging the stray capacitance producing a rapid fall time and/or, if the other charging switches are on, reestablishes the capacitor charging current. By controlling, the turn on of the discharge and charge switch of each section a dynamic voltage waveform can be produces (Figure 2) both higher and lower voltage with discrete voltage steps.

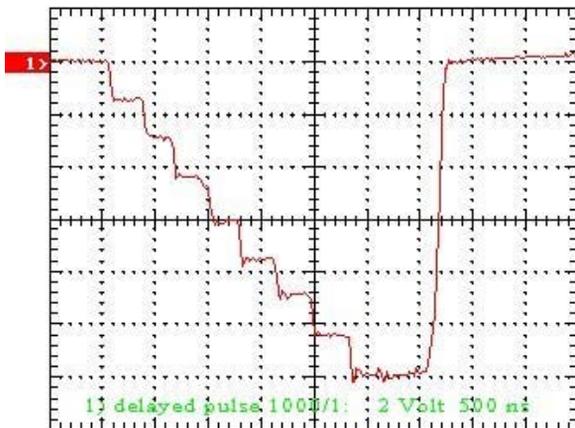


Figure 2: Dynamic Voltage Waveform

Multistage Marx Modulator Development

A first prototype, 14-stage multistage modulator was fabricated, tested deliver to Fermi Lab for testing on the Tevatron Electron Lens Tune Compensation System. (See figure 3) The modulator consisted of identical independent driver stages, which were plugged into a “mother backplane board” which made the connection between driver cards. (Figure 4) Each stage was independently triggered by a fiber optical line with control of the triggers determines the output voltage pulse. The prototype system was only a fixed amplitude fast pulse to operate at 50 kHz. Each stage was operated at a nominal one kilovolt producing a 14 kV pulse. The rise time was less than 150nS using IGBTs as the switches, with a pulse width adjustable for 0.25 μS to >1μS.

(Figure 5) The rise and fall times were demonstrated. Spark down testing using spark gaps demonstrated its ability to recover from load break down.

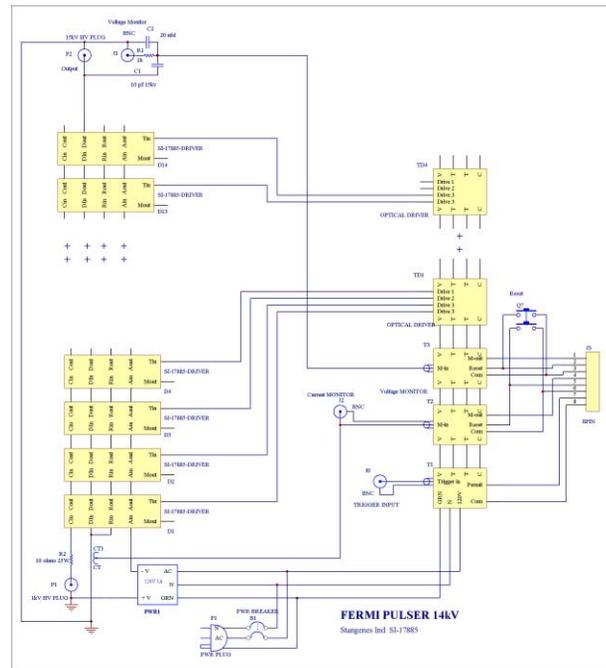


Figure 3: Modulator Block Diagram



Figure 4: Prototype modulator drivers and motherboard

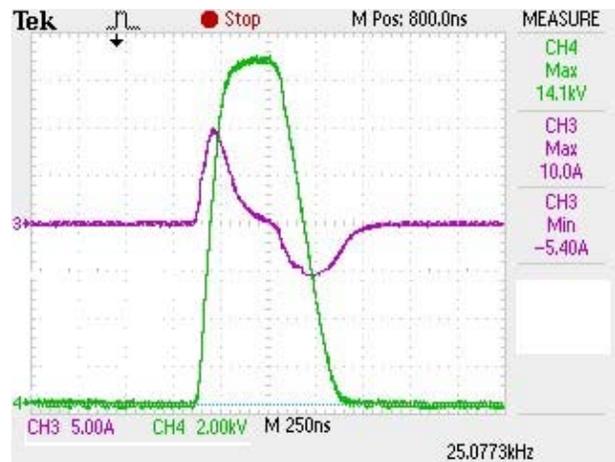


Figure 5: Output pulse short

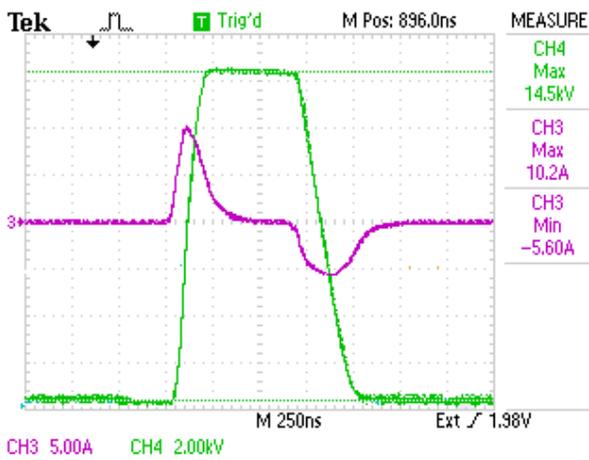


Figure 6: Output pulse wide

Due to cooling problems with the IGBT switches, continuous operation was limited to 25 kHz with burst mode to over 50 kHz. The unit was shipped and has been in operation.

FURTHER DEVELOPMENT

A second modulator was designed and is under fabrication to 14kV, at 50 kHz with discrete dynamically adjustable output voltage. The new modulator will have improved cooling. It is capable of using high voltage FETs to increase the rise time and fall time of the modulator if required. The IGBT/FETs are water cooled to allow for greater than 50 kHz operation. (See figure 7)

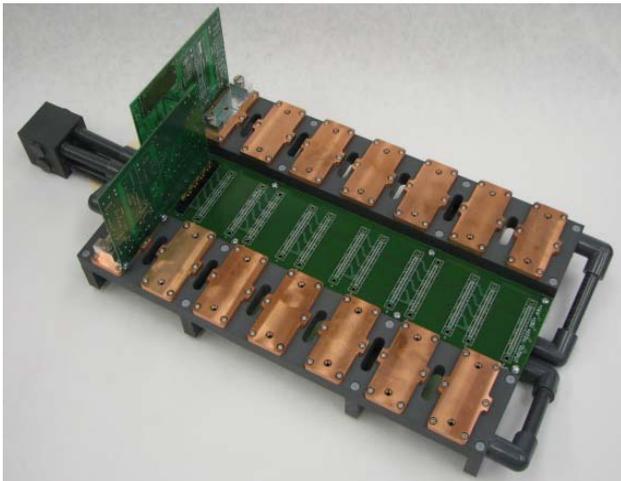


Figure 7: Water Cooled for Fermi dynamic modulator

SUMMARY

The Stangenes designed solid-state multistage Marx modulator has demonstrated that it can be used to provide a fast rise and fall time at high repetition rate. In addition, it can produce a dynamic amplitude and pulse duration at high voltages. With the improved cooling, it well is

capable of higher repetition rates. If the IGBTs are replaced with FETs, the modulator can have a faster rise and fall time at a lower output voltage

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- [3] Damping ring kickers for the Next Linear Collider, *Pappas, C. Cassel, R.L.* Particle Accelerator Conference, 1999, Volume: 3, page(s): 1500-1502 vol.3: 3/27/1999 - 04/02/1999