Saturating magnetic Max Bank drives mismatched loads , using the method of self matched lines.

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Abstract: The saturating magnetic Max Bank, provides a versatile topology to produce rectangular high voltage pulses with little secondary distortion. The self matched line method, is employed to achieve this. Rapid recharge is intrinsic, allowing high rep rate operation.

The Max Bank, switched using saturating magnetics, is a highly versatility topology. It allows stacking and adding, and pulse compression, in a high voltage pulse generator. Moreover arcs will not damage it. The unit cell of the Max Bank determines the nature of the output. Here we employ the very cleaver, self matched line. This allows the output to drive mismatched loads with near perfect fidelity, There are no back end, line reflections to consider as this topology suppresses them. The circuit inherently allows rapid reload, which is a major problem for the Marx topology(Ref1).

Max Bank operation overall

The topology employs floating drive cells charged in sequence by a long rectangular , low voltage drive pulse. These cells are capacitive in nature and are fed by common mode choke (CMC) isolators. The drive pulse feeds the vertical transmission line path consisting of CMC feed line inductance and the cell's capacitance. See Fig4. The drive pulse travels from bottom to top where it hits the open end, and the line voltage doubles, and is reflected back to the input driver. Just as the drive pulse returns to the source, saturating magnetics switch and all cells fire in unison. This provides ripple synchronization and pulse compression of the added pulses from the unit cells. For more information on this see Ref 2.

Timing

Here we see in Fig1 the output pulse appears, just at the end of the drive pulse, as desired. This is accomplished by setting the ET product of the cores to switch at the right moment. The drive pulse is 1200 V amplitude and output is 2.7 kV. Measurments were made with a Tektronix TDS644 oscilloscope and P6015 HV probe. Bandwidth of measurments is limited by the probe, to 90 MHz. Drive pulse length is 200 nS.

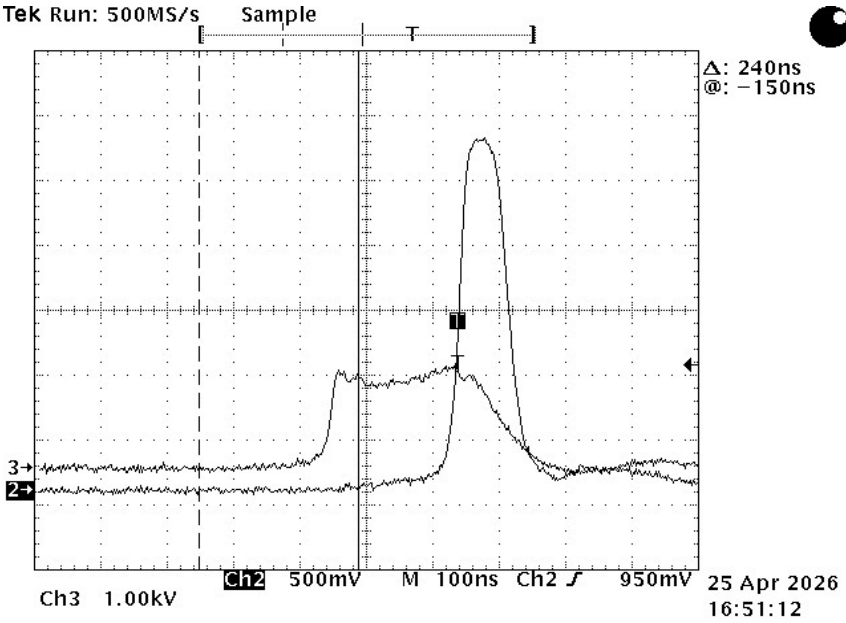
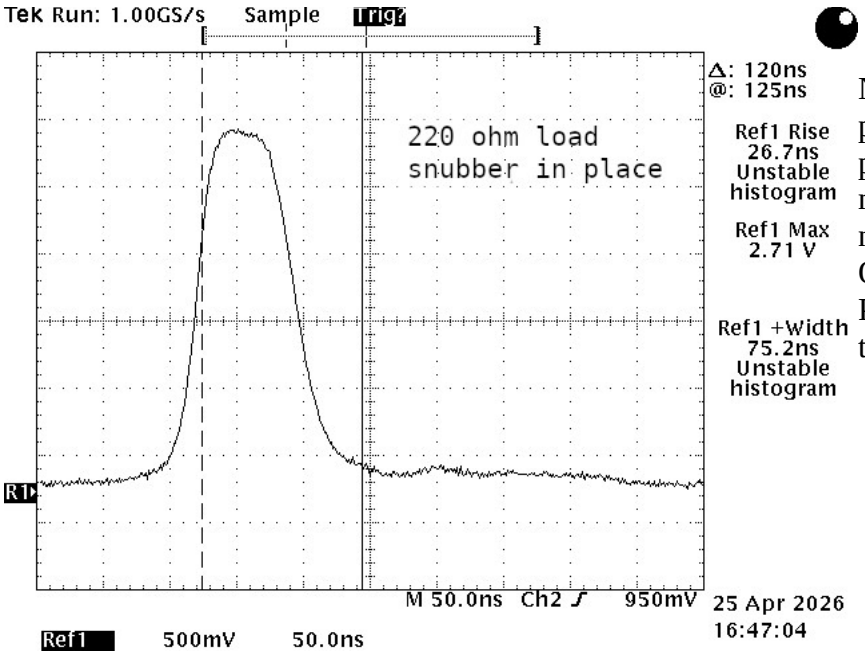


Fig 1 Timing of Drive Pulse

We see the output of the system (Fig1) consisting of a two stage Max Bank. Materials were limited, so only a two stage device was built. This is sufficient to see the problems encountered. Load is 220 ohms. Intrinsic impedance of each drive cell is 60 ohms , and so Max Bank source impedance is 120 ohms. A gross mismatch was tested in that way. Note the pulse is very clean as shown in detail in Fig 2. Here a small snubber was placed at the output consisting of 100 ohms and 60 pF C, to dampen a small leading overshoot.



Notice the clean pulse with little post pulse structure a charged line type pulser would produce, when grossly mismatched. This shows the effective nature of the self matched line. Output is 2.71kV peak. (500V/div). Post pulse structure is minimal. Rise time 27 nS and pulse width75 nS.

Fig2 Output Pulse into 220 Ohm Mismatched Load

Self Matched Line Cell.

The self matched line (Ref 3) is shown in Fig 3. This is the unit cell used for the device described here. The most common schematic is depicted on the left. Reconfigured as a saturating cell, the circuit converts to the right side of Fig 3. Here the transmission line is made up of a lumped LC ladder of 9 ladder elements. It is shown as a transmission line cable, but this is very hard to draw, and a symbolic notation is used for convenience. Assuming the line is 50 ohms, the function is as described. Assume the line is charged up initially. Saturating switch is open, looking at the right side, of Fig3. (Length, tau of pulse output).

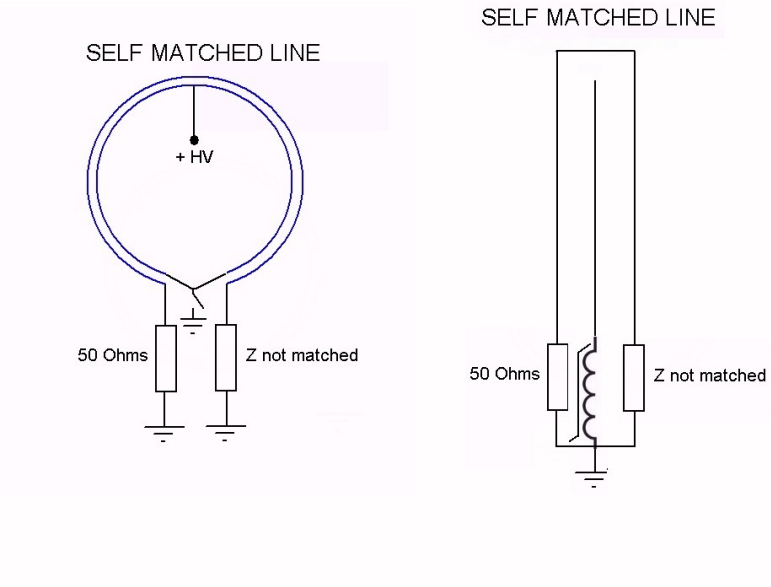
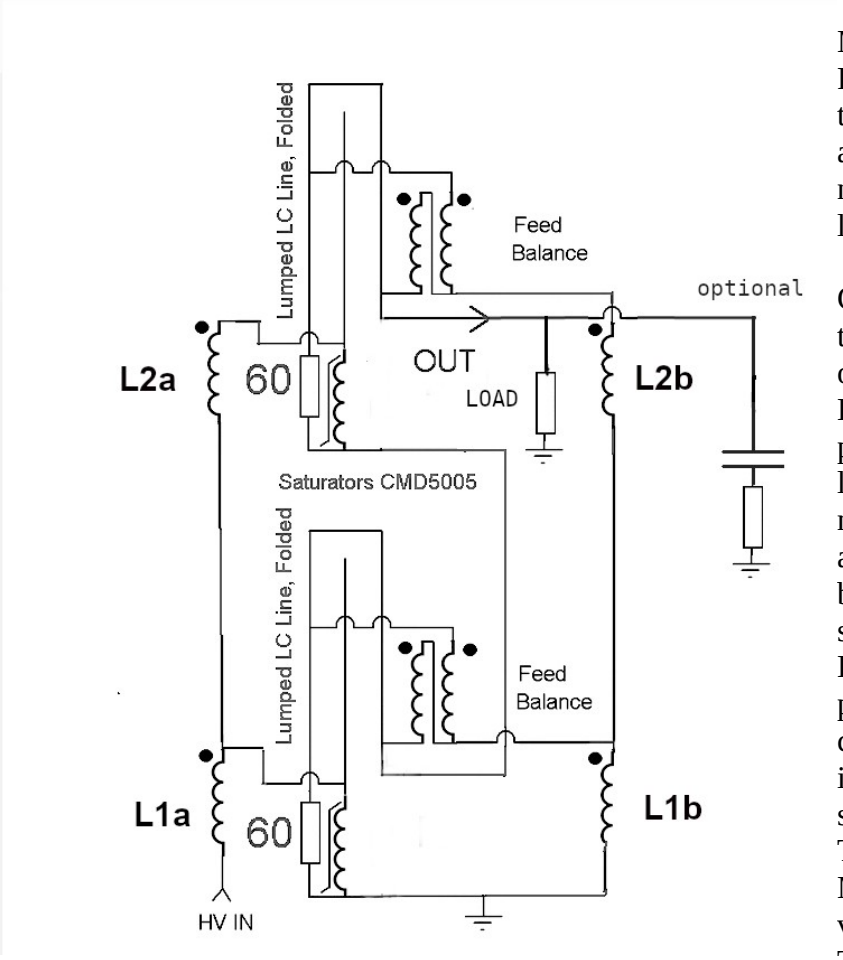


Fig 3 Self Matched Unit Cell

After the specified delay time, the saturator connects the ground line of the two sides of the transmission line, to system ground. When this happens, two events happens simultaneously. The left side of the line is discharged through the matched terminating resistor (50 ohms). The right side of the transmission line is delivered to the output load, assumed mismatched. The mismatched error voltage is transmitted counterclockwise around the line to the left end where the 50 ohm load absorbs the error voltage. This component does not reflect off the left end, as a normal un-terminated line would. Hence the reflection from the left end of the line is suppressed, by the switched load.

This switched 50 ohm load on the left end of the transmission line, is very unique and provides elimination of return reflection to the output. Hence the output pulse is determined by simple voltage division between the charged line, and the mismatched load. Reflections are thus eliminated.



Max Bank Generator
Fig 4 shows the detailed schematic of the pulser. Note the back terminations are 60 ohms, as this implementation needed that for the lumped element lines, used in the prototype.

Charging of the lines is done by the twisted pair, transmission line wound on the common mode chokes, L1, and L2. These inductors are in series and provide the drive path, to the charged line capacitance. Another balancing magnetic was needed, as it suppressed a pre-pulse artifact that appeared before the primary pulse evolved. The saturators were CMD5005 ferrite. Because of the tightly twisted feed pair, through the CMC string, charging is very rapid. From Fig 1, it is seen to be about 200 nS. Both saturators see the same ET drive. They ripple fire as a conventional Marx would do. The uniform pulse verifies the ripple fire.
The output pulse is shown with various mis-matches below. Note the

Fig 4 Max Bank Pulse Generator

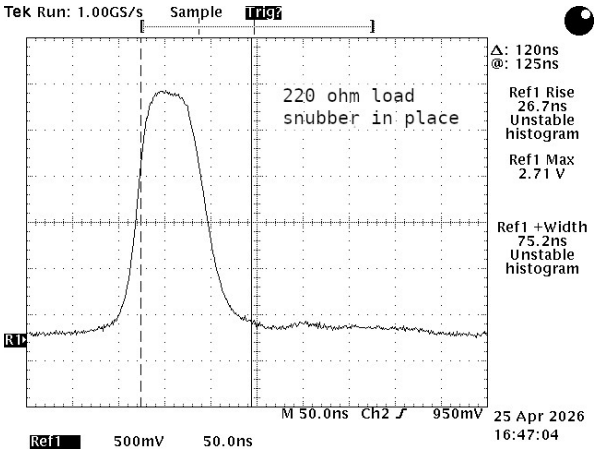


Fig 5 220 Ohm Load

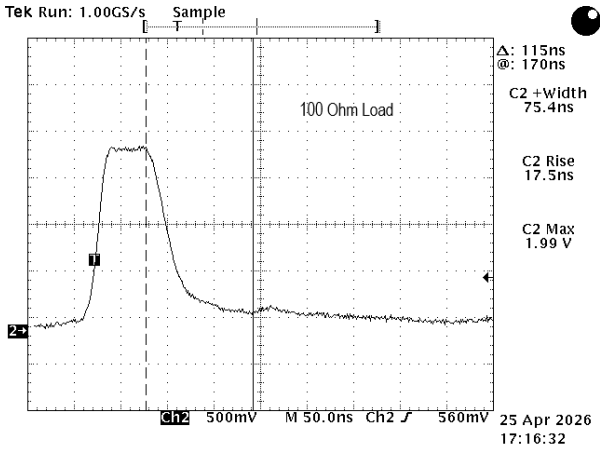


Fig 6 100 Ohm Load

absence of post pulse structure. The 220 ohm load produced a slight overshoot, and the optional snubber (100 ohm, 60 pF) was put at the output as indicated in Fig4. This is for an 83% over mismatch, 2.71 kV amplitude. The generator is a 120 ohm source, as built. Alternately the generator was loaded with 100 ohms, and waveform is shown in Fig 6. (No snubber used). For a 17% under mismatch, the output is very clean. 1.99 kV out. Almost no post pulse structure in either case. Display is 500V/div.

Conclusion

The Max Bank generator configuration, combined with the self matched line topology, produces amazingly good wave forms. Saturating magnetics often produce many post leading edge, artifacts. This method addresses that problem well. Saturating magnetic Max Bank generators are a new field of design, for the High Voltage engineer. Intrinsically they are robust against arcing, and reload is very fast, allowing for high rep rate operation. This solves two key problems of the conventional Marx Bank, described in Ref 1.

References

1. Marx, Erwin (1925). "Versuche über die Prüfung von Isolatoren mit Spanningsstößen" Elektrotechnische Zeitschrift. 45: 652–654

2. Artusy, Max (2026). “Max Bank: a saturating magnetic Marx generator” doi: 10.5281/zenodo.18728066 , 10.5281/zenodo.18728067 alternately https://vixra.org/pdf/2602.0079v1.pdf

3. M. Ishii and H. Yamada (1985).”Self matched high voltage rectangular wave pulse generator” Review of Scientific Instruments 56, 2116 (1985); doi: 10.1063/1.1138430 .

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