Complementary-Output PIN Diode Driver for Animal Imaging

B. L. Beck[1,2], J. E. Slade[1], and H. Zeng[1,2]

[1]McKnight Brain Institute, University of Florida, Gainesville, FL, United States, [2]National High Magnetic Field Laboratory, Tallahassee, FL, United States

Introduction: One of the basic operations of a diode is that of a switch, with forward bias the theoretical equivalent of a short circuit and reverse bias an open. However, there are many diode types, with performance changing accordingly. Diodes can be made with varying levels of P and N doping, the structure of the P-N junction can be manipulated, and different types of terminals can be bonded to the die for connection to real circuits. The characteristics of a PIN diode are specially suited to switching applications in MRI; i.e. in coil decoupling circuits. The PIN, an acronym for the type of semiconductor material used in making the diode (P-Intrinsic-N), has very low resistance when forward biased with appropriate current (typically 60-100 mA) and very low capacitance when reverse biased with appropriate voltage (typically 15-30V). In addition, they are able to dissipate tens of Watts of power. Animal imaging systems may or may not have PIN diode drivers built into the console. If not, the driver has to be home built or bought commercially at very high price (we obtained a $4000 quote). Consequently, we have built a dual channel, complementary output, high power PIN diode driver for less than $300.

Methods: A typical small animal imaging system does not come with a body coil built into the bore. Consequently, transmit-only volume coils that are actively controlled with PIN diodes must be built if receive-only surface coils are to be utilized. We built an 8-leg birdcage coil for this purpose, operating at 200 MHz in a 4.7T, 33 cm Oxford magnet with Varian console. The transmit-only coil had a PIN diode controlled decoupling circuit in every leg of the birdcage. The diodes were Microsemi series UM4000 with 0.4 Ω of resistance at 40 mA forward bias current, 2.4 pF of capacitance at 15 V reverse bias voltage, and average power dissipation to 37.5 W. From the DC perspective, there were 8 diodes in parallel, which required the PIN driver to switch between -15 V for reverse bias of diodes during transmission portion of MR experiment and 320 mA forward bias (40mA through each diode) during the receive portion of the MR experiment. The PIN driver circuit was based on an NPN-controlled PNP current source [1] shown in Figure 1. The resistor R9 determined the output current and consisted of four, 1 Watt, 150 Ω resistors in parallel, with an equivalent resistance of 37.5 Ω. Four parallel resistors were required so as not to exceed individual resistor power specifications. R9 could be easily changed to output any desired current if care was taken not to exceed power specifications of the resistors and current limitations of the transistors. The high current PNP transistor, 2N2907, had a maximum current rating of 800 mA. The 5V trigger from the MRI console was fed into a voltage amplifier (LM7501) for conversion to 15 V, then into 15 V CMOS inverters that generated two opposite trigger signals to feed two PIN driver circuits, creating the complementary outputs. Gerber files of a PCB were sent to Sunstone Circuits for fabrication. The PCB was housed in a plastic project enclosure, along with a dual output ±15V 1A/1A power supply (MEAN WELL, PD-2515) shown in Figure 2. BNC chassis mount connectors were used for the trigger input and complimentary output signals.

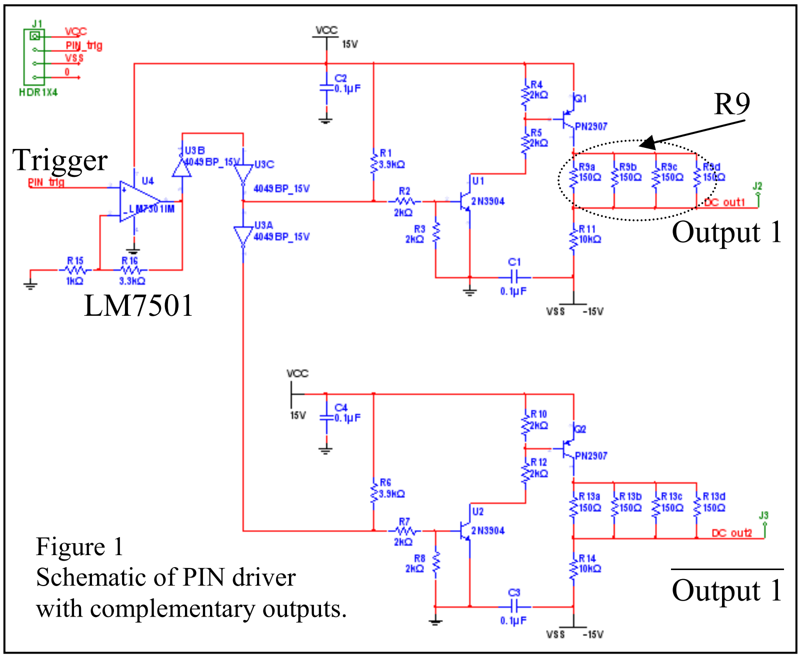

Figure 1
Schematic of PIN driver
with complementary outputs.

Results: The output of the unloaded driver is shown in Figure 3, with triggering at the top and complimentary outputs at the bottom. The driver successfully toggled between ±15 V in response to the trigger. The output of the driver attached to the TX-only birdcage was measured at 300 mA forward bias current and -15V reverse bias voltage. A spin echo image was acquired with a receive-only quadrature half saddle coil inserted into the TX-only birdcage.

Conclusions: A PIN diode driver with high current, complementary voltage outputs has been made and demonstrated. The driver was used to switch a TX-only birdcage into operation during MRI transmission and disable during the acquisition window. The driver was activated by MRI system TTL trigger signal (0-5V), but able to reverse bias the PIN diodes with high voltage (-15V) due to an amplifier circuit within the driver. The forward bias output current could be easily configured to any desired value by changing a single bank of resistors within the circuit. The complementary outputs allowed active control of PIN diodes on transmit-only and receive-only coils simultaneously. The driver was inexpensive and built for under $300. The authors are willing to share parts list and Gerber files of the PCB layout.

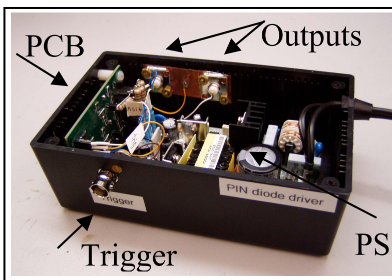

Figure 2
PIN diode driver with driver PCB, power supply, and BNC input & outputs.

Figure 3
Oscilloscope traces: Top is TTL trigger (0-5V), Middle is *Output*1 (± 15V), Bottom is complementary signal $\overline{Output1}$ (not Output1).

Acknowledgments: MRI data were supported through the National High Magnetic Field Laboratory and obtained at the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) facility in the McKnight Brain Institute of the University of Florida.

References

[1] Garbow JR, et al., Concepts in Magnetic Resonance Part B, 33B(4):252-259 (2008).