Benjamin Palumbo - Portfolio

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Pages **2-3** contain selected work related to my professional career.
Pages **4-7** contain selected products developed for personal use or for sale through my LLC.

Professional

Project descriptions below are intentionally vague due to non-disclosure agreements.

Multi-output semiconductor plating supply (PVD process). 12V 100A, 750V 4.5A, and 120V 10A DC outputs. Single or three phase input.

My duties included:

- Porting LWiP to STM32H7 due to issues with STMicroelectronics implementation. STMicro's network interface did not properly handle dropped connections, leading to heap overflow.
- Porting our proprietary CANbus driver from STM32G4 to STM32H7.
- Writing a new Modbus driver, as the existing driver did not support coils and discrete registers, and its data structures were written such that it would not meet the timing requirements of this project when scaled.
- Implementing Modbus PSU control with <=3.33mS latency (from Modbus/TCP frame to PSU setpoint stabilization). The power supply needed to meet these timing requirements of the customer's existing VxWorks installation. This required extensive fine-tuning of the LWiP stack and RTOS.
- Writing a universal USB DFU bootloader tool due to broken compatibility with STMicroelectronics vendor tool.
- Architecting a state machine to match customer's control requirements.
- Implementing and calibrating 16-bit ADC readbacks over Modbus.
- Board bringup of new fiber optic ethernet PHY.

Medical grade 200W 120VAC UPS

My duties included:

- Reverse engineering via black box attack PIC24F microcontroller PFC firmware due to lost source code and schematics. Re-wrote firmware based on recreated schematics and observed behavior under a variety of test conditions. Firmware controlled a standard single phase boost PFC, managing >0.98 power factor.
- Writing a new charging heuristic for lithium iron phosphate and lead acid "dumb" batteries. The prior firmware was only compatible with "smart" batteries using SMBus.
- SoC estimation via coulomb counting + OCV measurement.
- Re-write minor aspects of the DCDC control firmware to match new customer specs, such as fan speed curve.

3-phase 380-480 VAC Input 68kW 830V DC single output resonant charger for Ion Implantation

Contains four liquid cooled “Liqua-Blade” single DIN power supplies, consisting each of three DCDC forward converters with active PFC.

My duties included:

- Architecting the state machine to match the customer’s requirements.
- Writing a DSP algorithm to calculate an instantaneous and rolling average of AC input voltage and current RMS values. Reasonable accuracy was ensured with zero crossing tracking. Current imbalance was used as a proxy for ground fault in lieu of a current transformer on the protective earth. Filters were added to remove AC line harmonics.
- Adding full SEMI F47 compliance.
- Writing I2C driver for IO expanders.
- Board bringup, rework instructions, and rework of the system baseboard. The system baseboard required extensive modifications.
- Handle various error states based on data from inside the unit and externally from the customer (discrete IO).
- Handle CANbus readbacks and setpoint commands from the liquid cooled power supplies (internal CAN network).

3-phase 380-480 VAC Input 80kW Arbitrary Waveform Generator for Crystal Growth Furnace

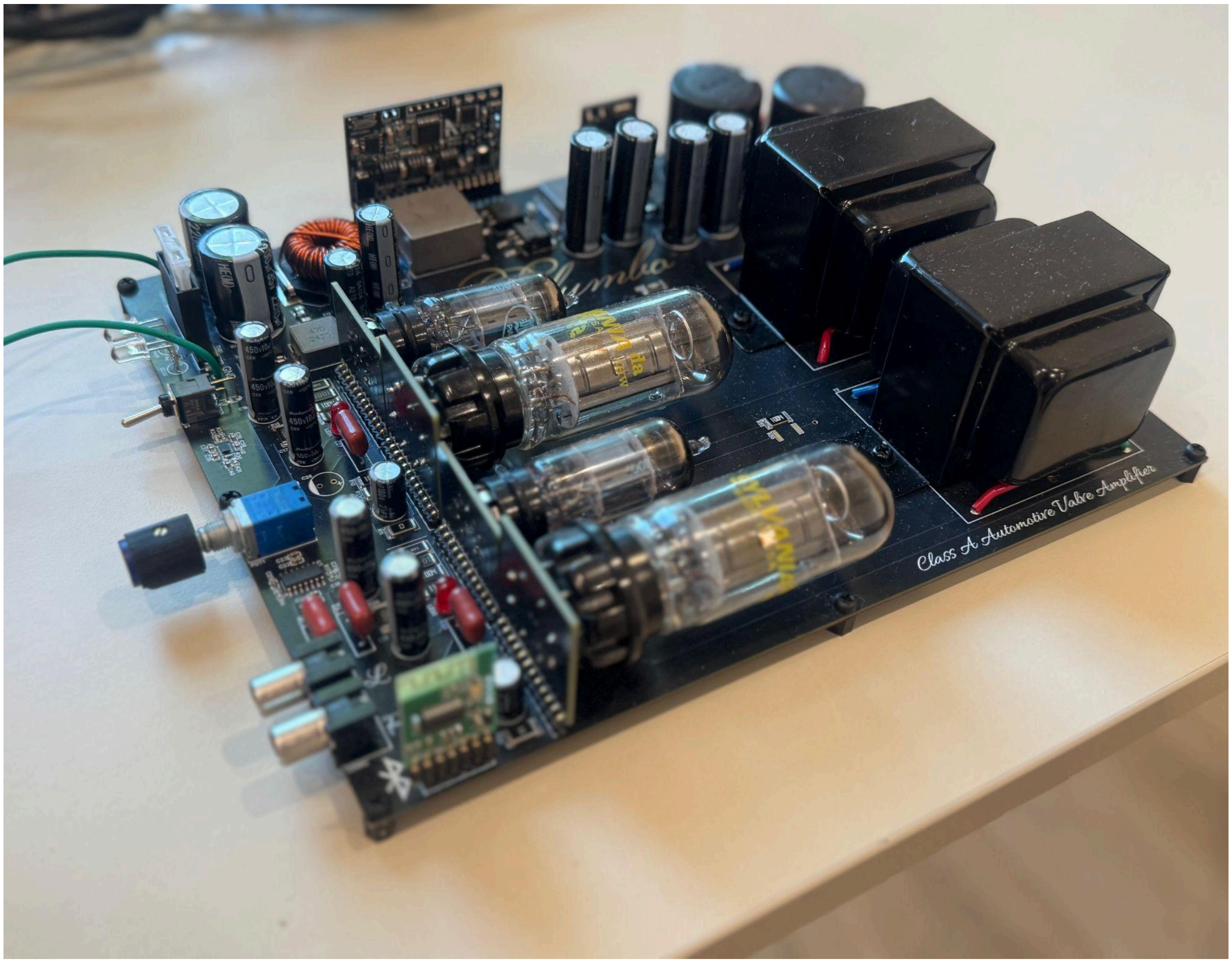
My duties included:

- Arbitrary waveform generation in firmware based on user request from companion GUI.
- Output waveform RMS voltage and current readbacks.
- Board bringup, which included modifications to the isolated power supply for CANbus, and changing differential amplifier scaling and filtering.
- Writing CANbus gateway firmware to allow bootloading of the individual AWG modules (wired in parallel in system) from the master controller.

Personal & Small Business

Automotive valve amplifier, 12V nominal input, 11W stereo output

Built for retro tube audio from a vehicle or portable 12V battery source



A ground-up Class A stereo valve amplifier designed to run entirely from a 12V supply. The core challenge is generating the high voltages required for tube operation from a low-voltage automotive source, while keeping switching noise out of the audio signal path.

Performance

- 5.5W per channel output power
- 0.75% THD per watt
- 62W total system power draw
- Minimum operating voltage: 10V

Power Supply

The most significant engineering challenge in the design. A two-stage boost converter raises 12V to 325V for tube B+ bias. Off-the-shelf inductors with adequate saturation current and inductance were unavailable, so bulk capacitance was added to both boost stages to handle the resulting high ripple current. An interleaved boost converter for the first stage was considered to help mitigate this issue, but bulk capacitance is less expensive than additional magnetics, FETs, and control circuitry. The boost converter achieved 92% efficiency at typical load.

Tube heaters are powered from a separate buck converter at 6.3V, chained to a 5V LDO, which feeds a ±5V charge pump supplying a JFET op amp input stage for high input impedance.

Digital Control (Power Supply Daughtercard)

- STM32G4x MCU using the high-resolution timer peripheral
- IXYS gate drivers (×2) for the boost stages; Microchip high-side driver for the buck
- Three independent PID loops maintaining tight output voltage regulation
- Overcurrent and output short detection via duty cycle deviation and output voltage sag as proxy measurements
- Undervoltage lockout below 10V input
- Modular daughtercard format chosen for serviceability, with the acknowledged disadvantage of increased distance from the switching loop
- Control for "12V" and "Power Good" indicator LEDs

Safety (Energy Dump Daughtercard) Normally-on depletion-mode NMOS circuit that actively dissipates stored energy in the boost capacitors when the gate isn't driven. Thus, it continues to function after input power is removed, an important safety consideration given the 325V B+ rail.

PCB Layout

- 4-layer stackup
- Tight core switching loop geometry with solid ground plane on layers 2 & 3 around all switching elements
- Hatched ground plane in audio sections (layers 2 & 3) to minimize parasitic capacitance from forming a low-pass filter.

Audio Signal Path

- JFET op amp input stage with bandpass filter
- 12AX7 preamp tubes biased using red LEDs as low-noise shunt regulators
- RCA inputs with header for auxiliary audio interface daughtercard (Bluetooth module pictured)
- 6V6 power stage

4-Speed Transmission Controller

Built to retrofit a GM 4L80e/4L85e into a 1978 Datsun Pickup

A ground-up hardware and firmware design replacing the factory transmission control module. Supports both modern CANbus ECUs (OBD2 Mode 1, rusEFi, and OBDonUDS/J1979-2) and legacy discrete analog sensors, making it compatible with a wide range of engine management setups.

Hardware

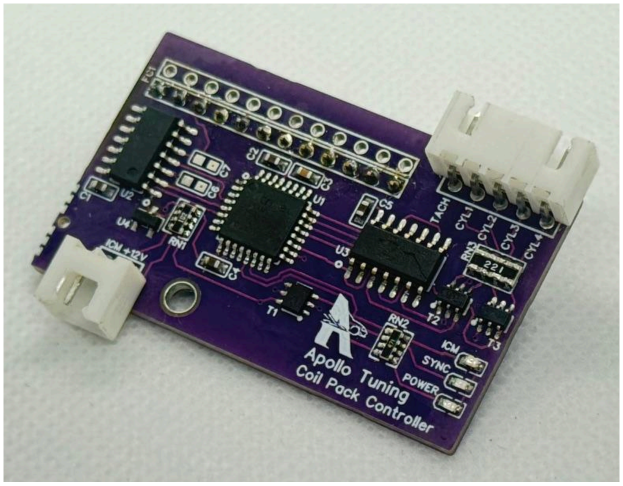
- ISO 16750-2 compliant power supply with external 5V sensor bias for analog sensors
- CANbus interface with 3000V galvanic isolation and common-mode filtering.
- Dual-channel VR conditioner ASIC for transmission input/output speed sensors, with firmware-configurable zero-crossing tracking
- Dedicated ASIC hardware debouncing on two user-configurable inputs
- Auxiliary outputs for speedometer, radiator fan, reverse lights, and malfunction lamp.

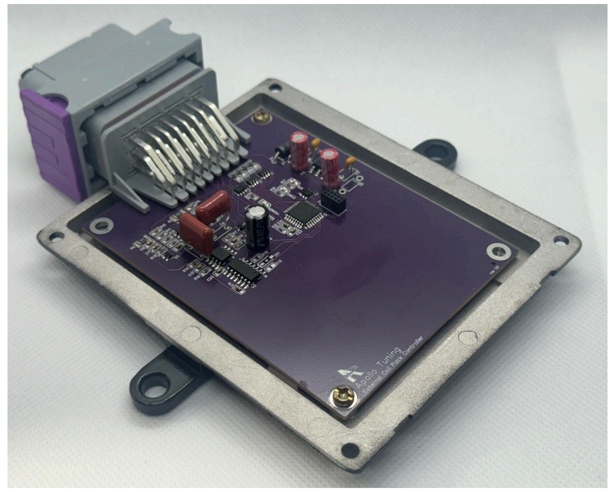
Firmware

- Shift scheduling, torque converter lockup, and line pressure control via polynomial curves referenced to a user-selected sensor
- Optional closed-loop pressure PID
- Paddle shifter support and full manual valve body mode
- USB configuration utility with live datalogging
- Field-updatable firmware via bootloader; companion GUI is independently updatable

Coil Pack Controller | Internal & External

Built to retrofit individual coil-on-plug ignition onto a 2000 Honda Civic Si





A hardware/firmware solution for converting single-coil distributor ignition systems to individual coil-on-plug. Engine position tracking is handled in firmware with igniter demultiplexing in hardware. This keeps signal latency in the nanosecond range, resulting in negligible timing deviation at high RPM.

It is available in two variants:

Internal - installs directly into the factory engine computer. Limited to compatible ECU models, but requires no external wiring or power supply.

External - standalone unit for any 1988–2000 Honda. Adds a discrete VR sensor interface and an ISO 16750-2 compliant power supply; otherwise identical hardware and firmware to the internal version.

Both variants include:

- Hardware demultiplexing for nanosecond-range signal latency
- IO protected against shorts to ground and battery voltage
- ISO 7637-2 compliance
- AEC-Q rated components throughout