Phoenix HF RF Amplifier
Rebuilding and Modernizing the Icom IC-PW1

Amateur radio is an experimental science. As enthusiasts, we conduct radio frequency communications experiments, develop new technology and construct electronic equipment and radio antenna systems. In addition, we often troubleshoot and repair the electronic equipment we use in our radio operations.

This article describes troubleshooting, repair and upgrades to an Icom IC-PW1 RF amplifier. Without going into specific details, I was asked if I could repair two separate PW1 amplifiers owned by two amateurs here in Alberta.

The IC-PW1 is a solid-state RF amplifier that was first manufactured by Icom in 1999. The IC-PW1 was one of the first commercially available solid-state 1 kW HF amplifiers and quickly became popular among contest and DX operators. This product was discontinued by Icom and thus replacement components, especially circuit boards, are difficult to impossible to obtain.

The Icom IC-PW1 had many innovative features including:

- One (1) kilowatt nominal output power
- Operation for ten (10) amateur bands, 160 m through 6 m
- Built in automatic antenna tuner
- Switchable input (2) and output (4) RF connections
- Firmware monitoring of all important operating parameters
- Remote control head connected by cable
- CI-V control available

■ General

- Frequency coverage:
  1.800– 1.999 MHz
  3.500– 3.999 MHz
  7.000– 7.300 MHz
  10.100–10.150 MHz
  14.000–14.350 MHz
  18.068–18.168 MHz
  21.000–21.450 MHz
  24.890–24.990 MHz*1
  28.000–29.700 MHz*1
  50.000–54.000 MHz
  *1The USA version can only be used the antenna tuner on the 24–28 MHz bands.
- Antenna connector:
  Input PL-239 × 2 (50Ω)
  Output PL-239 × 4 (50Ω)
- Usable temperature range:
  –10°C ~ +40°C (14°F ~ 104°F)
  (Except Antenna tuner)
  0°C ~ 40°C (32°F ~ 104°F)
  (Only Antenna tuner)
- Power supply requirement:
  non-Europe versions
  100–120 V AC or
  200–240 V AC (±10 %)
  Europe version
  230 V AC (±10 %)
- Dimensions (W × H × D):
  Liner amplifier
  350 × 265 × 375 mm
  13.8 × 10.4 × 14.8 in
  Remote controller
  205 × 71 × 68.3 mm
  8.1 × 2.8 × 2.7 in
  (Projections are not included)
- Weight (approximate):
  28 kg (61.7 lb)
  (Remote controller is included)
- CI-V connector: 2-conductor 3.5 (d) mm (⅛˝)

■ Transmitter

- Output power:

MODE	INPUT AC VOLTAGE	
	200–240 V AC	100–120 V AC
CW, RTTY	1 kW	500 W
SSB	1 kW PEP	500 W PEP

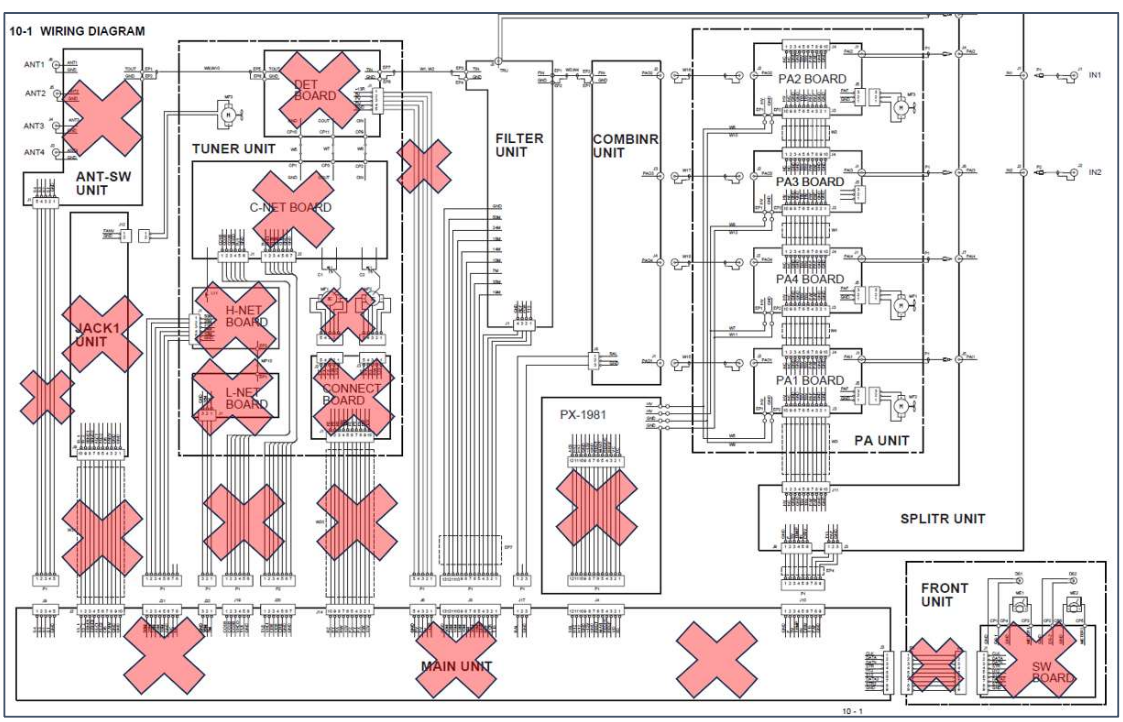
- Driving power: 100 W maximum
- Spurious emissions: –60 dB (HF bands)
  –70 dB (50 MHz band)
- SEND connector: Phono (RCA)
- ALC connector: Phono (RCA)

■ Antenna tuner

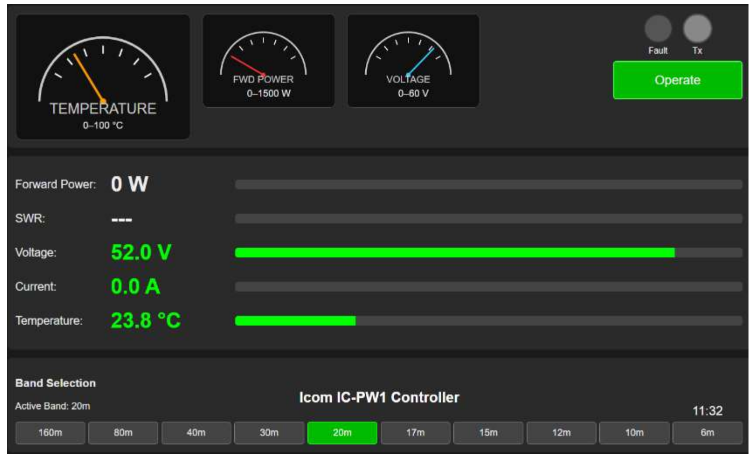
- Matching impedance range:
  HF bands*2 16.7 to 150 Ω unbalanced
  (Less than VSWR 3:1)
  50 MHz band 20 to 125 Ω unbalanced
  (Less than VSWR 2.5:1)
  *2The USA version can only be tuned within 1.80–1.95MHz of the 1.8 MHz band.
- Minimum operating input power:
  60 W
- Tuning accuracy: VSWR 1.5:1 or less
- Insertion loss: Less than 1.0 dB
  (after tuning)

Both amplifiers suffered from multiple failures including a defective power supply, control circuitry issues, and damaged interface electronics. It was reasonable and time effective during the troubleshooting process to simply replace defective components in one amplifier with parts obtained from the other. The IC-PW1 has many well documented failure points within its overall system architecture and internet information searches greatly assisted in the diagnosis of the multiple electronic failures that had occurred on both amplifiers. In a fairly short time frame, a working amplifier was returned to its owner in Edmonton.

Unfortunately, the second amplifier was essentially gutted with non-functional power supply, control head and main control board. I realized that replacement and repair to original factory condition was problematic. It was decided a practical path forward was to rebuild and modernize the amplifier while removing a significant number of non-essential or defective components (marked with Red X below).



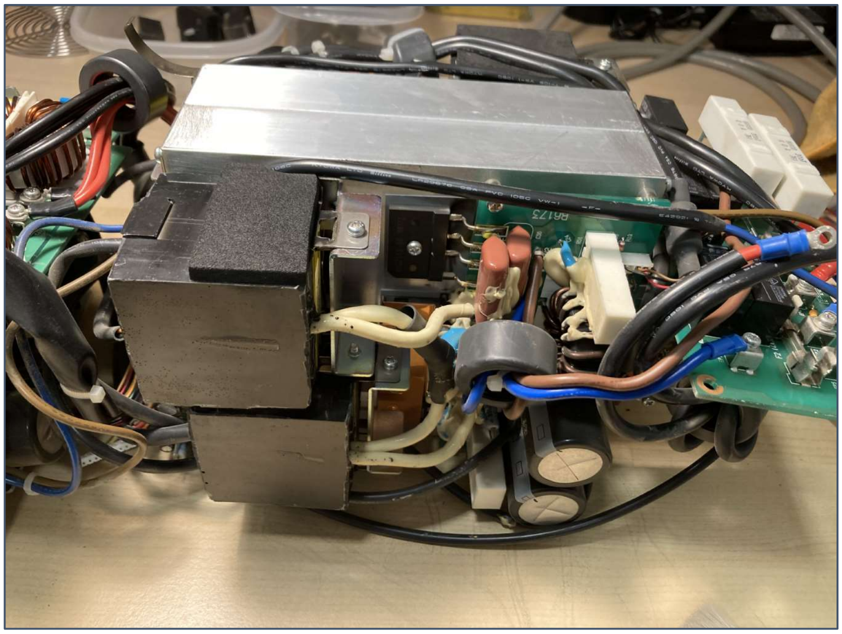
The rebuilt amplifier is shown below along with a web-based control interface that controls and monitors the amplifier using ethernet LAN connection and remote Windows based computer.

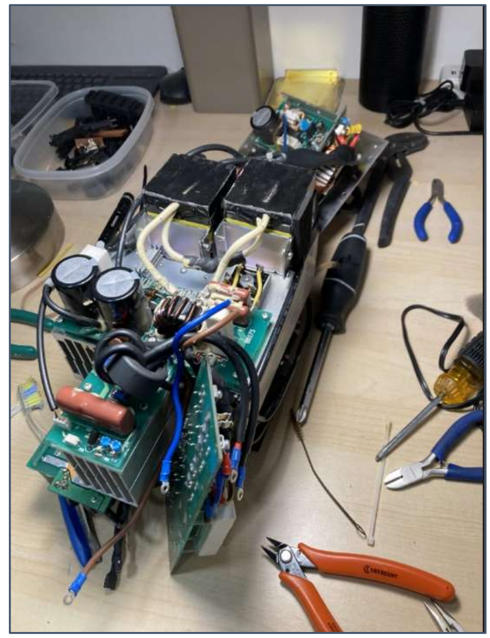


The amplifier is controlled by an Arduino UNO R4 microcontroller, running C++ firmware and a JavaScript-based web interface. I had zero expertise in software programming and graphical user interface development prior to this project. Amateur radio provides an environment to learn and develop new skills that provided considerable enjoyment to me during this PW1 rebuild and update. To be clear, this was not an easy project and presented considerable technical challenges with the occasional frustration when "*things*" simply did not work. However, as I learned through many years working in the energy sector, "*it is best to focus on the solutions rather dwell on the problems.*"

Power Supply

The IC-PW1 power supply is known to be problematic and many articles are available that document both technical issues and solutions. The nonfunctional power supply was removed from its case and is shown below.



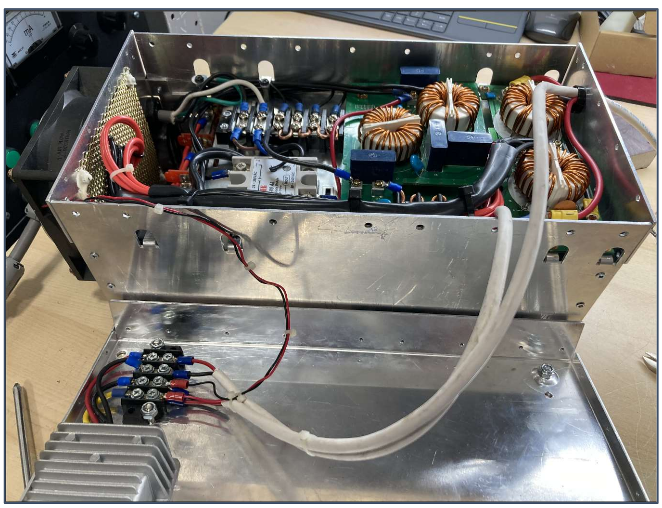


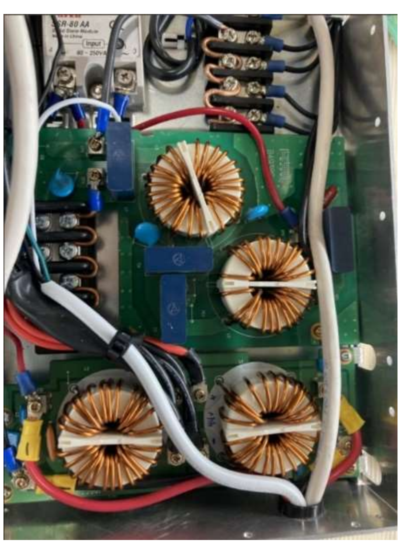
Several modular switching power supplies were available and I proceeded to replace the defective power supply with this device.

The Cordex CXRF-HP series of 48 Volt, 1.2kW, rectifier modules employ high frequency, switch mode technology featuring high power conversion efficiency. All internal semiconductor devices operate under “soft-switching” conditions and exhibit very low power loss. The reduced power loss leads to lower thermal stress on the semiconductors and thus improves reliability.

Power Supply

Four Cordex rectifier modules were installed in parallel within the PW1 power-supply chassis, providing 48 VDC at approximately 100 A (4.8 kW capacity). The PW1 RF deck operates from a high-current 48-volt DC supply, making telecom rectifier modules an excellent replacement option. A 48 Volt DC to 12 Volt DC converter module was also placed within the power supply chassis. This 12-volt source would be used to power the Arduino R4 microprocessor and band switched low pass filters within the amplifier. The rebuilt power supply has significant capacity and overcomes many of the limitations of the original factory unit.



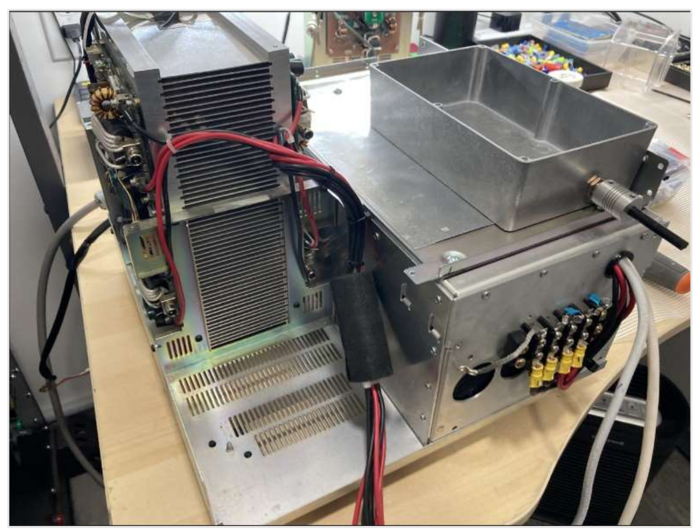


AC and DC filters obtained from the original PW1 power supply were reused within the rebuilt power supply. A solid-state relay is controlled by front panel on/off switch to energize / deenergize all power supplies. Thermal cooling is provided by front and rear fans.

Power Supply

Telecom rectifier modules such as the Cordex series are widely available on the surplus market, highly reliable, and designed for continuous high-current operation. Fan intake ports are shown for the rebuilt power supply (partially hidden by external wiring). It was somewhat coincidental that the four Cordex power modules were a 'perfect fit" within the existing power chassis. Using this construction method the new power supply could simply be a direct "drop-in" replacement within the overall PW1 amplifier.

The RF low pass filter is illustrated at the rear of the photograph. Eight (8) selectable filters are used for the 10 operating bands. A common filter is used for both 17 m / 15m and 12 m / 10 m bands.

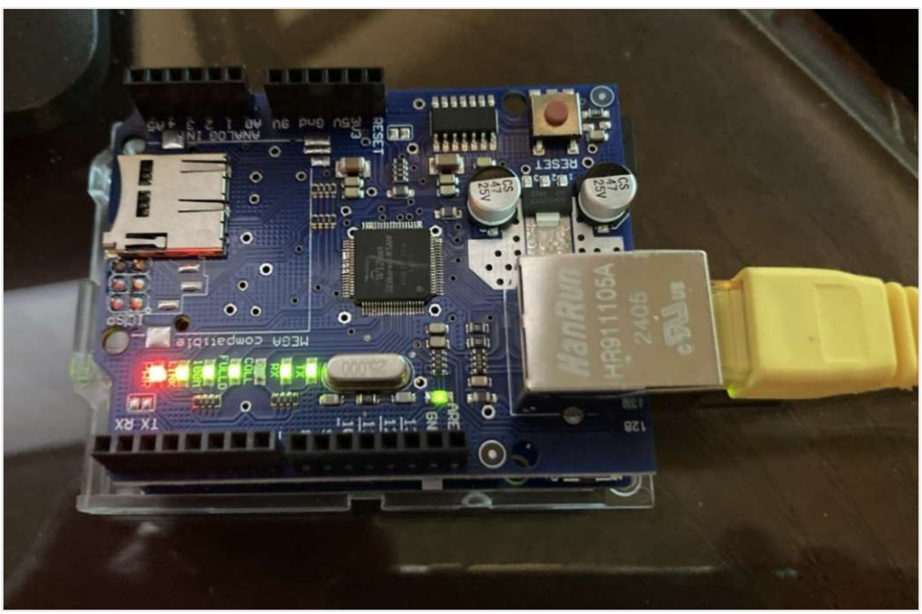


The photograph on the right shown above illustrates an early "mock-up" assembly. An aluminum box placed on top of the power supply was to contain a rotary ten (10) position switch used to control the low pass filter selection. After some time and thought, I discarded this control procedure and started a much more ambitious plan to provide control of the amplifier.

Microprocessor Control

Today, some form of CPU is present in almost all electronic devices, from the vehicles we drive, to the phones we use, to kitchen appliances that supply us with the essential coffee. Amateur radio is no exception, microprocessors are common in modern RF transceivers, amplifiers and many other hardware items that we use during our radio communications activities.

I had purchased an Arduino UNO R4 WIFI sometime in the past with the objective of learning how to use this type of device. Sadly, the microprocessor sat in my parts bin and was neglected due to other priorities that appeared.



Fortunately, I remembered that I had this device and wondered if I could use it to both control and monitor the PW1 that I was rebuilding. This seemed reasonable especially with the sub $50 price tag for the device, it appeared to be a low-risk endeavor. However, a microprocessor without software simply uses electricity and does little more. As previously indicated , I had zero expertise in writing software to control complex operations and monitor hardware functions. In addition, I wanted a modern graphical user interface (GUI) to which I had even less experience or knowledge how to create or code.

Software Solution

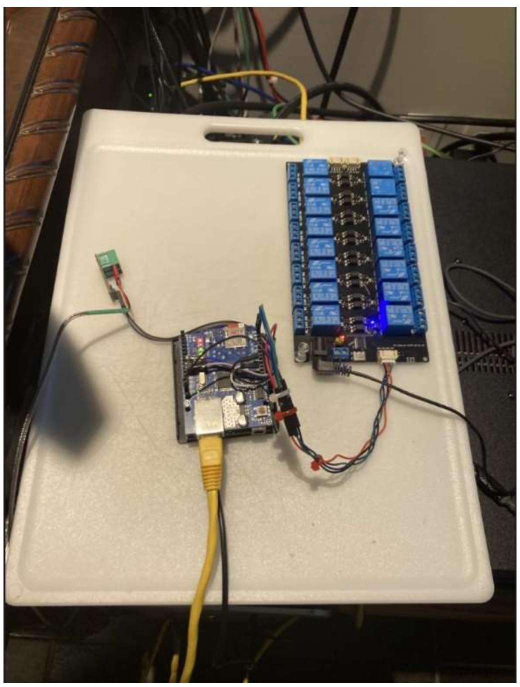
Significant technology changes have occurred since my beginning in amateur radio with construction of a crystal radio receiver and 6V6 vacuum tube transmitter. Today, as radio amateurs, we enjoy access to information and technology that is truly remarkable. One such technology is the AI platforms that are widely available through the internet.

I commenced a process to develop PW1 control software with the assistance of the AI program ChatGPT. Through software development the following specifications were identified:

- Control of the amplifier either from front panel push buttons or a web-based GUI operating through a LAN on a remote windows computer.
- Web-based GUI to provide band change functions for low pass filter selection.
- Realtime display of amplifier output power, VSWR, PA Voltage, PA Current and Temperature
- Monitoring of VSWR, Voltage , Current and Temperature and automatic amplifier shutdown if any parameter exceed defined limits.
- Band hot switch protection to disable amplifier in case a band change is activated during transmission. (N.B. this was an earlier defect in the original PW1 design which resulted in amplifier damage for numerous operators.)

Software Solution

ChatGPT was used as an engineering assistant during development, helping generate code examples, debug problems, and suggest hardware interface approaches. However, it was an extended interactive and iterative process with some 30 to 40 versions of software being created and tested before the system worked adequately. My experience using ChatGPT may be described as dealing with two unique individuals, one a brilliant technical expert, the other a rebellious teenager that does not follow instructions.



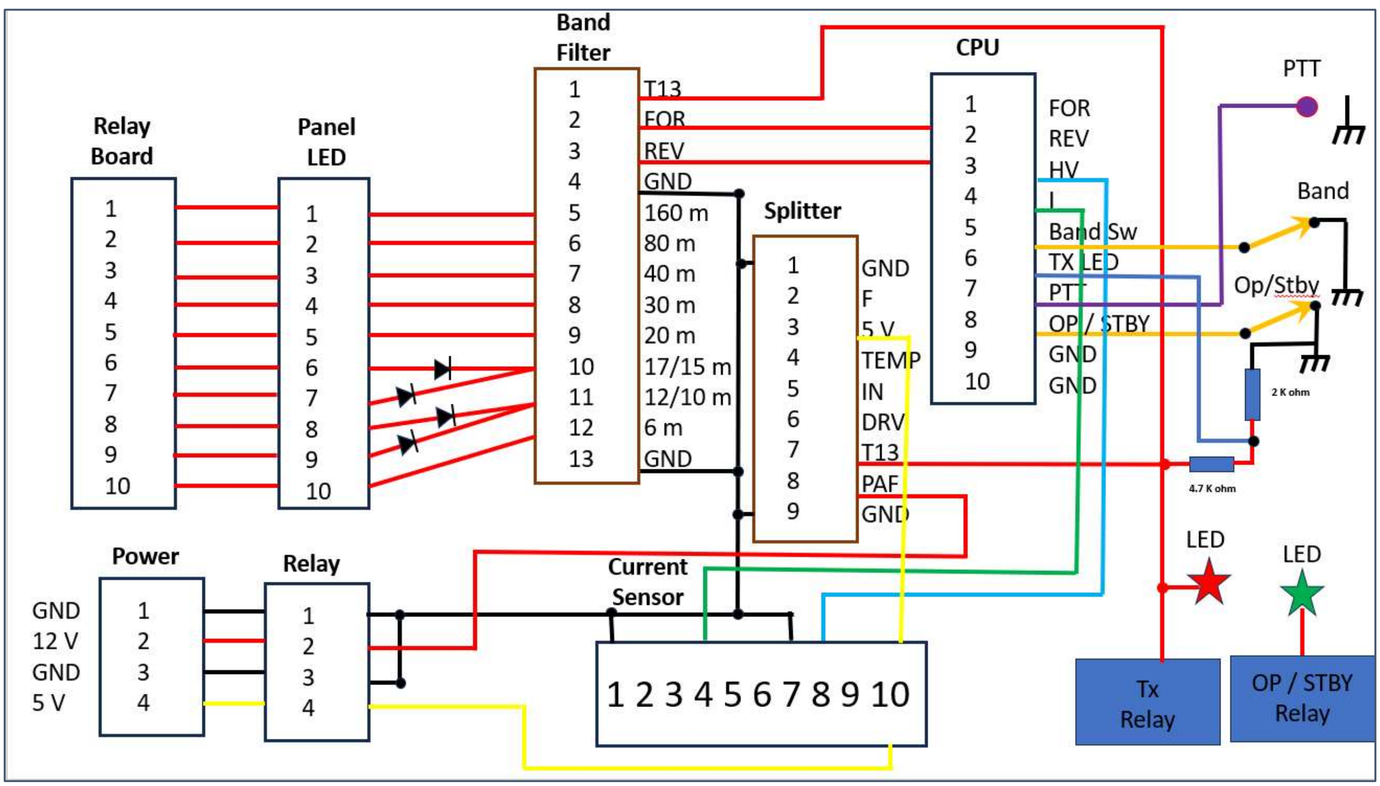
Gradually, I learned to communicate effectively with the ChatGPT application, however the initial weeks Microsoft seemed to have the teenager working most of the time rather than the technical expert. I breadboarded the Arduino Uno R4, an Ethernet shield, a temperature sensor, and a I^2C-controlled 16-port relay module during software testing.

(Yes, that is a real breadboard borrowed from XYL!)

Through the hardware / software development a multitude of challenges occurred with the selected Uno R4 device. While they are too numerous to document in this article, I will state that ChatGPT was very helpful is solving these problems that first appeared unsolvable to me.

Hardware Interface

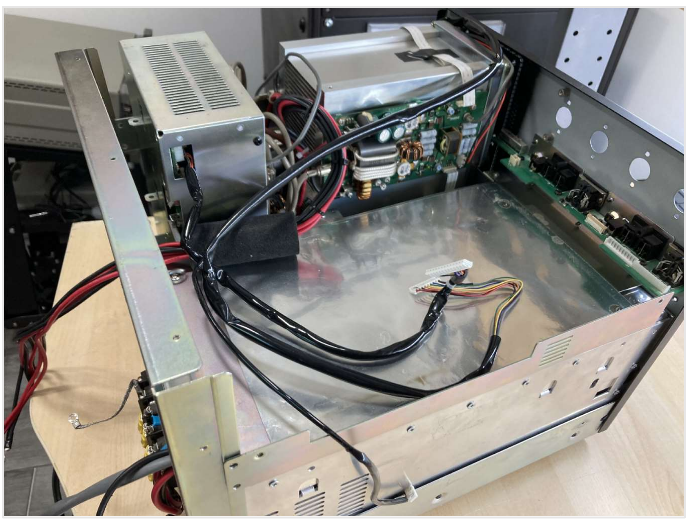
After achieving a workable software application, I created a circuit diagram to show the interface connections between the microprocessor i/o ports and the PW1 hardware. I was familiar with the original PW1 circuit diagrams through my extensive review of them while repairing the first PW1 amplifier.

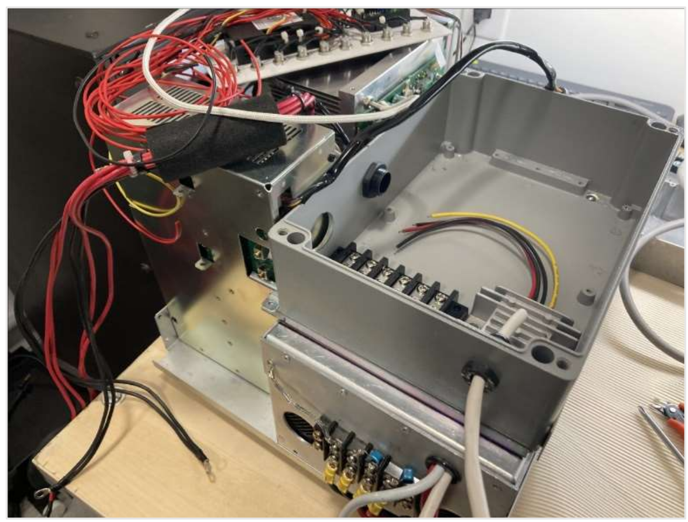


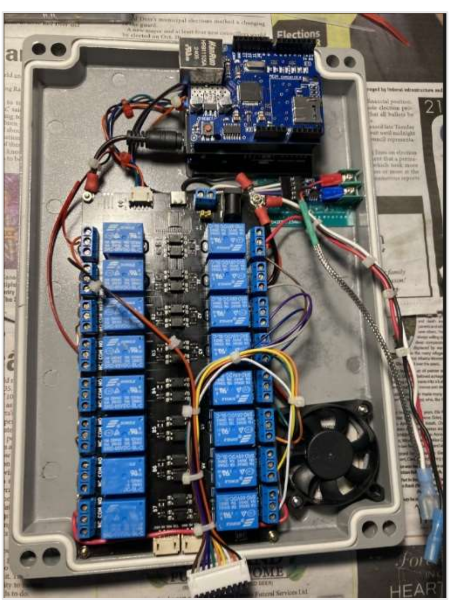
An objective of the PW1 rebuild was to simply the overall design and enhance the robustness and reliability of the entire system. In addition, modifications to component layout enhanced the ability to troubleshoot, repair or modify the amplifier if required

Hardware Assembly

The antenna tuner unit (ATU) and main board chassis were removed from the original PW1 components. An aluminum case was sourced and would be used to contain the Arduino Uno R4 microprocessor and related sensor and control circuitry. This case was selected to measure of RF shielding between the high-power RF amplifier and the electronics section of the amplifier. The Uno R4 and relay board were mounted on the inner top lid of this case. The interface board was mounted to the inner bottom of the case and provided all connections plus voltage and current sensors.







Hardware Assembly

The amplifier may be controlled either by front panel push buttons or remotely from a computer via a wired LAN ethernet connection. Amplifier PA voltage, PA current and temperature are displayed on the front panel. Power, standby / operate and band change buttons with corresponding band LED indication.

A Hall-effect sensor is used to measure final amplifier current a transfer data to UNO R4 for monitoring and display. This sensor was a cost effective and practical method to measure the high DC current values present during amplifier operation.

Appropriate grounding, shielding, and RF bypassing were implemented to ensure stable operation and to prevent RF interference with the control electronics.

Summary

The IC-PW1 rebuild was an extensive project with many technical challenges that required innovative solutions. This project provided significant technical learning as well as introduction to modern software development and programming skills. Like many projects undertaken by radio amateurs, I have concluded and the completion of this project that I would likely do the design differently if I where to repeat the process again.

I consider this project successful in restoring a non-functional amplifier back from the ashes to an enhanced and fully functional RF HF high power amplifier.

All modifications were performed for experimental and educational purposes by a licensed advanced class amateur radio operator.

```
RF Deck
   |
Low Pass Filters
   |
Arduino UNO R4
   ├── Ethernet Interface
   ├── Relay Control (PCA95x5)
   ├── Temperature Sensor
   ├── Voltage Monitor
   └── Current Hall Sensor
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VE6HQ Phoenix HF RF Amplifier

About the Author

Don has pursued a lifelong interest in science and engineering beginning as a youth in western Canada. He received his first amateur radio license at the age of 15 while attending high school in Edmonton, Alberta, Canada.

Don continued this interest and graduated from the University of Alberta receiving a Bachelor Science in Electrical Engineering. During the last 41 years he has worked in the Energy Exploration industry in Canada, the United States, Europe, South America, the Middle East and the Far East.

His technical area of interest led to publications of nuclear magnetic resonance applied to reservoir characterization. He was granted numerous US patents for developments of wireline pressure core technology. Don Westacott strongly considers training and technology transfer as an important part of his role within the E&P industry. Don accepted a role as guest lecturer at the Colorado School of Mines providing instruction to a new generation of petroleum engineering students. Don was honored to be the Distinguish Speaker at the Harvard University Energy Panel Arab Conference. During 2020, Don received the prestigious Hart Energy Innovators Award.

My first amateur radio license was issued in 1967 as VE6ANW. A year later achieved the advanced certification as VE6RI. I initially pursued 20-meter DX working using the Drake R4B / T4XB / L4B equipment and a 3 element Yagi/Uda antenna at 70 feet. Soon after, I became interested in weak signal UHF propagation. Constructing of a "home brew" 70 cm radio system complete with 4CX250 linear amplifier based upon a novel resonant coaxial cavity design was completed. Three hundred (300) kilometer daily communications using over the horizon tropospheric scatter was achieved between his Edmonton QTH and VE6JX located in Calgary, Alberta.

After more than 50 years have passed, I have rejoined the amateur radio ranks and currently active on 20 meters and VHF / UHF bands. I was granted the KI5KGX call as an extra class USA amateur operator. Subsequently, we moved to Canada and I reinstated by Canadian amateur radio certificate and requested my current call VE6HQ.

Don and his wife Marilyn enjoy the success of their sons Matthew and Andrew.

During 2023, I presented a webinar on UHF Test Equipment, which may be found at:

https://vimeo.com/906428996)