Multiband LO Project

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PNW VHF Society Conference Oct 12, 2019

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What does it do?

- Provides a stable LO source for multiple transverters at the correct level and frequency
  - Optional external 10MHz reference
  - Optional onboard high stability TCXO
- Provides a shared single configurable LO source
  - Lower total upgrade costs
  - Easier construction and parts counts when building new transverters
  - Lower retrofit effort compared to dedicated PLL units for each transverter
  - Based on an affordable low noise DigiLO PLL rated to 6GHz
  - Software changes could support other PLL units
  - Only 1 external 10MHz reference connection (if used)
  - Saves on 10Mhz reference source distribution equipment cost and space
- Easy construction using off the shelf function modules
- PTT In and Out translation
  - "Polarity" config for both PTT In and PTT Out for TX state = Hi or Lo

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What does it do? (continued)

- Digital Band In data (up to 4 wires) from a radio or external switch
  - Automatically selects a specific LO configuration and Band Out pattern
  - Configurable pattern covers parallel and BCD
  - Many radios offer digital band decode output
  - Analog band data not yet supported but easy to add – code mostly completed
  - Can enable/disable Automatic mode and use the front panel push switch to cycle through the bands
- Band Out data (up to 6 wires) for transverter and/or antenna selection
  - Configurable pattern covers parallel and BCD
  - Drives TTL or Lo-side controlled switches
- Displays GPS data and calculates 8-digit Maidenhead Grid Square location
  - Also useful for GPS or GPSDO units without a display screen
- Measure power output using a SMA connected power detector

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What does it do? (continued)

- Configurable menu-based system to tailor settings for most needs
  - Based on a simple database with 7 records
  - Very few limits
  - PC not required
  - Settings stored in EEPROM
- PCB designed for easier build
  - Acts as a breakout for the high number of CPU IO connections
  - Provides 5VDC and 9VDC power
- Configuration Data and Operations State stored in EEPROM
  - Several settings are saved immediately, others only saved when the Save Data menu item used
  - Factory reset menu item to restore default settings
 - Last Known Grid always displayed, stored in EEPROM

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What is in the box?

- DigiLO PLL– a low noise 6GHz rated PLL unit from DEMI/Q5 Signal
  - Standard or with High Stability TCXO option
- LCD Display and Rotary Encoder with Push Switch
- 31dB Solid state Programmable Attenuator rated to 6GHz
- 20dB Wideband Amplifier rated to 6Ghz and +21dBm max
- RF Switch – your choice solid state or mechanical with parallel interface (up to 4 wires)
  - I use SP6T TTL mechanical and solid-state versions
- Optional external 10MHz reference such as an OCXO or GPSDO
- GPS serial TTL level connection
- AD8318 based Log Power Detector
- PCB with 5 and 9 VDC regulators, connectors for each module and CPU
- PSoC 5LP CPU dev board module from Cypress Semiconductors

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Block Diagram
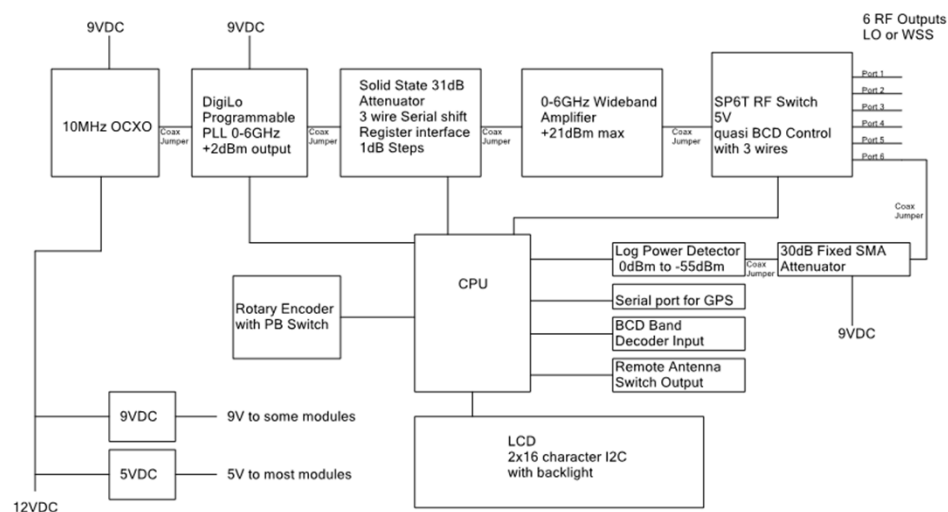
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Compact Version

- Shown here using the WSS version of the DigiLO. Replaced the DIP switch with a DIP socket.
- Small plastic box
- No OCXO used
- High stability TCXO option on DigiLO
- Solid State modules
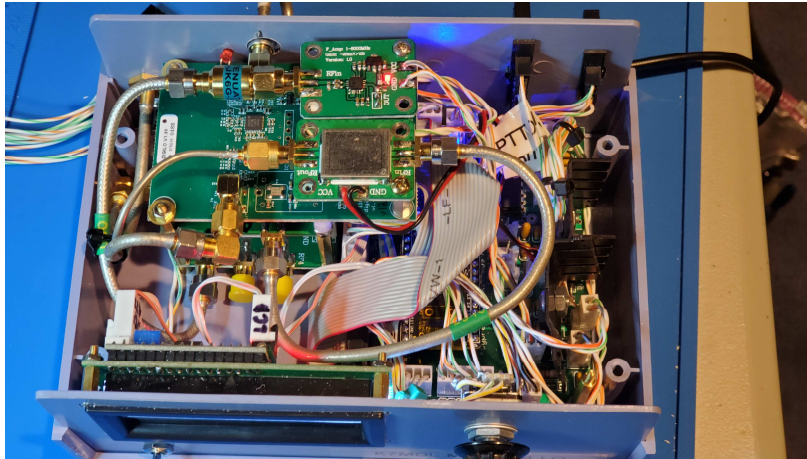- Goals was to be small and low power for easy use in the field

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Back Panel

- PLL lock LED from DigiLO
- 10MHz external Ref Input
- Jumper can be removed to bypass modules
- Power detector connected to Port 6 inside case
- GPS In
- Band In
- Band Out
- 3 of the 6 RF switch ports
- 12V power

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Compact Low Power Version with Solid State Modules

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Larger Build

- Internal OCXO used
  - Separate heater power switch used
- Mechanical SP6T Switch and Attenuator
  - Uses significant power
  - Heat is an issue
  - Attenuator 127dB in 1 dB steps but limited to less than 1.5GHz
- Metal box for heat sinking voltage regulators
- Small quiet fan inside
- Supplying LO to 5 transverters
- Switching antennas for 6 bands
- Transverters switched by KRC2 band decoder, K3 controlling LO box

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DigiLO 6GHz Programmable PLL

- Low Noise
- Optional High stability TXCO
- Can connect an external 10MHz reference
- Parallel interface, ground to select, 8 wires
- 255 preset frequencies covering common LO and WSS frequencies
- Small size
- PLL Lock LED
- Available from DEMI and Q5 Signal
- $99 for standard TCXO

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Programmable Attenuator

- 0 to 31.75Db in 0.25Db steps
- Parallel or serial control option
- Using 1dB steps and serial control for this project
- 5VDC
- Potential to chain more than 1 attenuator for a wider range of attenuation in other uses
- About $22
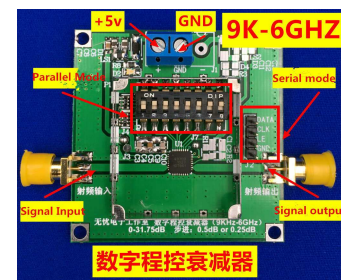

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Wideband RF Amplifier

- Operating Frequency: 5Mhz-6000MHz
- Amplifier Gain: 20dB
- Working Current: 85mA (5V)
- Power Supply Voltage: 5VDC
- System Impedance: 50ohm
- Size: 34*25mm/1.33*0.98in
- Max. Output Power: +21dBm(100mW)@1dB compression point
- About $10

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Solid State RF Switch

- Imported low cost semiconductor modules available in SPST, SPDT, SP3T, SP4T, SP6T and SP8T versions
- Limited frequency specs compared to mechanical switches
- Semiconductor and PIN Switch models
- HMC252 shown is 3GHz rated but will see up to 10dB insertion loss above 1.5GHz
- Modules available for other chips
- Uses less power and smaller than mechanical switches, 5VDC
- Parallel TTL interface (3 wires)
- Can be very ESD vulnerable (by my observation!)
- About $25
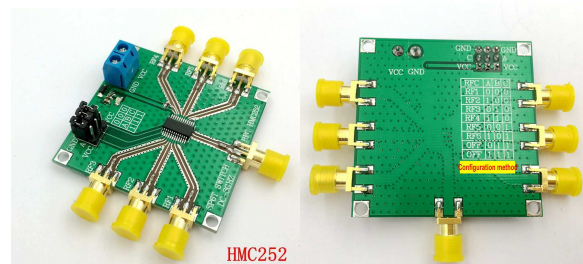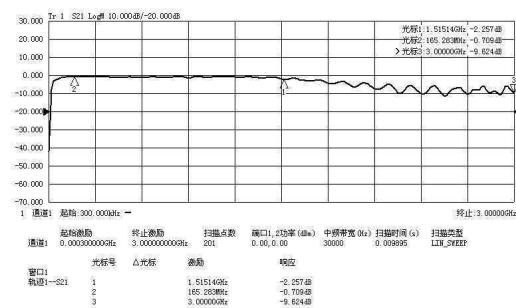
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Mechanical SP6T RF Switch

- Surplus switches usually found in 12, 24, and 28VDC versions
- TTL, high and lo side driver versions
- Usually supports 0-18Ghz in SMA versions
- Use more power than solid state but low loss at higher frequencies
- V1 PCB supports low side or TTL only
  - 12VDC versions are hard to find, TTL also harder to find
  - Finding a NOS switch at 12VDC and TTL drive is like winning the lottery but possible
- Surplus switches found around $50 each

- Can use small solid-state relays to level shift for high side drive switches such as Toshiba TLP222A
- Future PCB version I plan to use a configurable Hi/Lo side driver
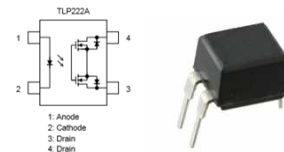
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# 8GHz Logarithmic Power Detector

- 70dB dynamic range
- Best accuracy 0dBm to -55dBm
- Usable +5dBm to -60dBm
- 25mV/dB
- 0.5-2.1VDC range output
  - 0.6VDC ~ -5dBm
  - 2.1VDC ~ -65dBm
- 5VDC power
- About $10
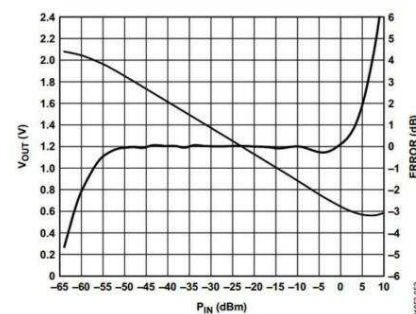
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PSoC 5LP CPU Dev Module

- PSoC 5LP based Dev board part # CY8CKIT-059 from Cypress Semiconductors and DigiKey for $10-$14
- PSoC = Programmable System on Chip
- Small size module with 2 26 pin headers for lots of IO, 100 pin chip
- Snap off programming board has smaller size PSoc5 chip, can be used by itself
  - Break off and use a 5 wire cable to connect them
  - USB to computer
 - Has USB bridge to connect to CPU module onboard USB port
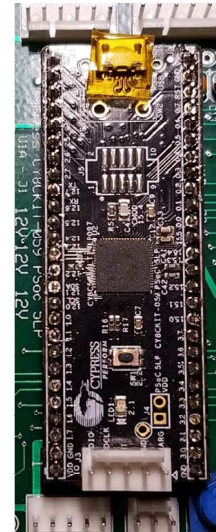
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PSoC 5LP CPU Dev Module (continued)

- On chip hardware function blocks
  - Comparators, amplifiers, signal mixer, RTC, voltage references, dividers, counters, timers, debouncers, deglitchers, logic (Flip Flops, AND/NOR/NOT etc), Mux, various types A/D and DAC, I2C drivers, RS232 and USB, PWM, status and control registers can consolidate disperse IO pins, power monitors, EEPROM, Flash, Clocks, and more
- All IO pins can be digital, many can be analog inputs or outputs
  - Some IO pins are capable of increased drive currents and level shifting between 3.3 and 5V
  - Inputs have configurable inputs
    - Hi, Lo or Hi+Lo 5K pullup resistors
    - Hi impedance digital or Analog
    - Drive hi or lo
    - Initial state can be defined at power on and a initialization
- Free IDE
  - C language
  - Schematic Editor to configure the on-chip hardware and IO pin configurations
  - Generates standardized APIs for each components
  - CPU code not required to make most hardware functions work

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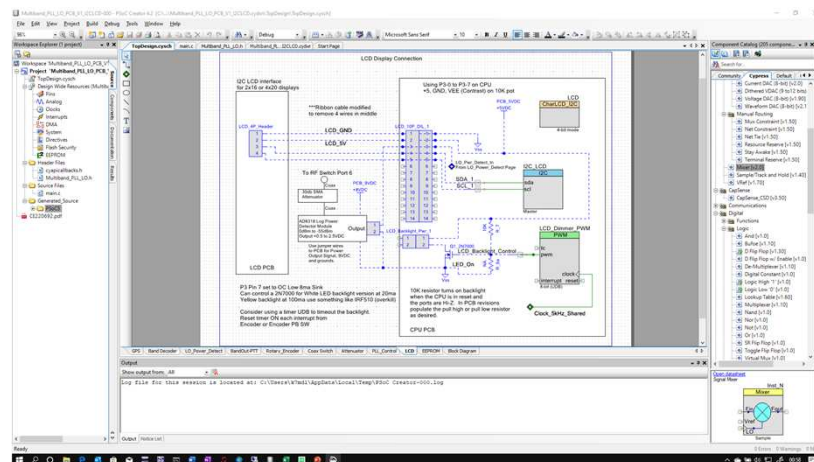# Assembled PCB with CPU Module

- PCB V1
- PSoC 5LP dev module part #CY8CKIT-059
- LCD parallel connector used but using serial LCD freeing up several IO ports.
- Power Detector on one of the free IO ports
- 5 and 9 VDC power
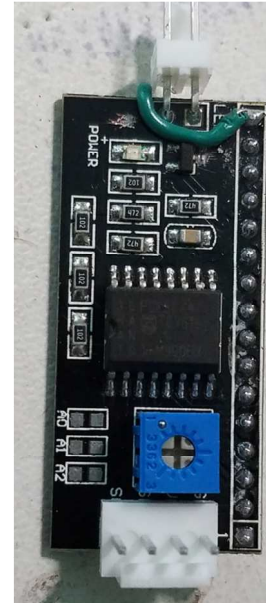- Lo side drivers for Coax and antenna switches
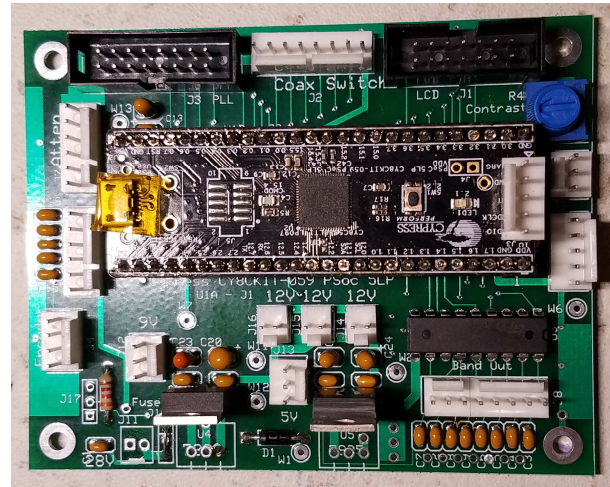
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Schematic Editor to Define Hardware Blocks

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IO Pin Assignment

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IO Pin Configuration Example

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LCD Display

- Standard 16 Character x 2 Line LED backlit display, Hitachi compatible
- Backlight current can be quite varied between models and color of backlight LEDs, up to 250ma on a yellow example
- The white LED model I am using is only 20ma
- Using a serial backpack to convert standard parallel LCD interface to a 2 wire I2C
- Must use version with PCF8574T interface chip for the interface library code used
- Modified to allow PWM backlight dimming

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Remote Antenna Switch with PTT

- SP6T 24VDC mechanical switches, Lo side drive
- 6" SMA to N bulkhead cables
- Aluminum plate for durability and heat sinking
- Small perf board for PTT relay to preamps
- LED status for PTT state on bottom
- Automotive waterproof 12 pin connectors
- 24VDC from 12V DC-DC converter in series with main 12VDC down control cable to remote box
- 12V regulator for preamp power
  - Several diodes in series to drop the voltage for reduced regulator heat.
  - Tolerates voltage drop better.

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How to use it?
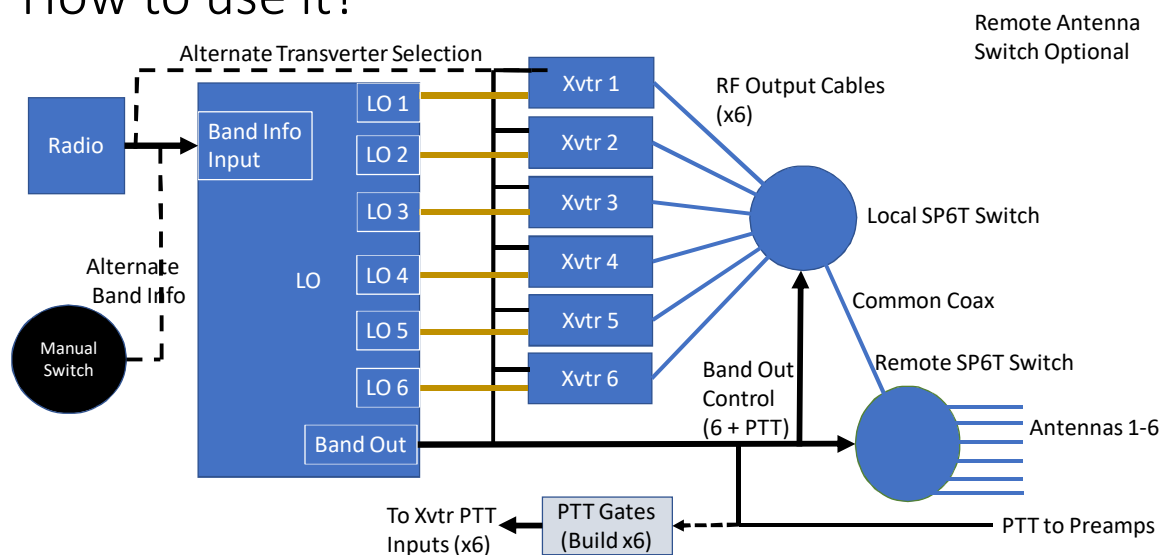
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Configuration Menu System Navigation Rules

- Extra long push is Change Screen Mode (>1.6 sec or until the screen changes)
- Long push is Back (0.5s to 1.6s)
- Short Push is Select (<0.5s)
- Rotate right to enter scroll list menus
- Rotate left or right to choose values
- Short Push to select a value
- In text entry menus the last value in the list is "Accept". This will commit the built-up text string. "Accept" will display when strings reach max length.
- Back and Change Mode abandon operation in progress.
- Most Config Menu changes are not saved in EEPROM until you choose the Save Data menu item in the Config Menu
- Operational state is saved immediately and on band changes

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Screens

- 3 Screen Modes
  - GPS Status (has 2 screens toggled by a short push)
  - Band Status (short push cycles to next band in Manual mode)
  - Config Menu
- Use Extra Long Push to cycle through the Modes
- Config Menu
  - Shows firmware version, callsign, auto band change enable, and config submenus that change all settings, save to EEPROM, and restores default settings (clear EEPROM)

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Config Submenus

- Band Name (any alphanumeric character in the list)
- Coax Switch Port (1-6)
- Frequency (select from list)
- Attenuation (0 to 31dB in 1 dB Steps, select from list)
- Band In (any value 0x0 to 0xF, select from list)
- Band Out (Any value 0x00 to 0x3F, select from list)
- PTT In (Hi or Lo on Tx, select from list)
- PTT Out (Hi or Lo on Tx, select from list)
- GPS (4800, 9600, Disable, select from list)
- Backlight Dimming (0 to 100% bar graph)
- Save to EEPROM
- Factory Reset

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Coax Switch

- Selects Ports 0 through 6
- 6 parallel output lines
  - Pattern is not configurable
- Ground to Operate, 500ma max
  - Can omit ULN2803A driver IC for TTL devices
    - Driver IC also acts as LCD Dimmer driver so need a replacement
- Solid Sate RF Switch or Mechanical RF switch
- Any band any port, even same ports, no limit
- I hooked up the internal power detector to Port 6 on the compact box

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Real time Attenuation, Frequency and Power

- When changing Frequency or Attenuation values are updated real time
- Handy for experimentation
- Power output will be displayed when the Band Name = "POWER" or the detected level > -20dBm
- Reconfigure Coax Switch Port to the one connected to the Power Detector
- Could bring Power Detector out to back panel and bypass Coax Switch
- Display at right shows the Attenuator being changed for the 432 band, LO output at -8dBm.
  - 0dB attenuation would be +22dBm

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Band In

- Up to 4 wires < 5V with internal 5K pull up resistor to 5V is configured on the input port pins
- For each band, set pattern to match via configuration menu
- Duplicate input pattern matches will select the 1st band to match
- Can use an external switch such as a BCD or rotary switch
- Auto switch enable/disable in Config Menu
- Auto Mode follows Band In pattern matches
- Manual Mode uses front panel push switch to cycle through the 7 bands.
- The Front Panel Switch short push is ignored in Auto Mode

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Band Out

- ULN2803A driver provide ground on each line
- Jumper any voltage to 28V on PCB to connect protection diodes in the chips
- The voltage is wired to the back panel connector to power the remote switches and preamp power
- Up to 6 wires can be used in any pattern per band determined by Config settings
- Can select the same pattern for any number of bands

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PTT In and Out

- The Config menu lets you specify the state for TX, Hi or Lo
- Both PTT input and output configurable Hi/Lo
- R2 and R3 and Zener Diode
- May need a pull up resistor added, depends on your gear
- PTT state displayed on the Band Status screen status, 3rd Charactor. From top left
- Onboard blue color LED is lit for TX = ON state from CPU point of view
- Input for TX_Inhibit function on the PCB and driver chip but not used today
- PTT status has no impact to any other operation of the unit
  - Does allow level shift when needed
  - For example TX = Lo in, TX = Hi out
- Future options include sequencing, coupling with TX_Inhibit, x6 PTT Line Out

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GPS

- Config menu offers 3 choices
  - 4800 bps
  - 9600 bps
  - Disable - removes the GPS mode screens
- Displays a calculated 8-digit Grid Square, Latitude, Longitude, Sats in View, SNR and Time. Tap the Push switch to toggle between 2 GPS status screens
- Time is extracted from GPS messages only as of today. Since the message rate is not predictable you may see jumps. Plan to use the 1PPS and/or internal 1 second timer to update the time every second.
- If no valid GPS serial message is received the display will clear all but the Grid Square and show time since last message. Wraps at 255 seconds.
- The last known grid square is stored in EEPROM and always displayed.
- TTL level interface
- RxData, 1PPs, Spare (for future TX), %VDC and GND
- I am using QRP-Labs QLG1 GPS kit mounted in a plastic case. It uses TTL level signals at 9600bps
- Could connect to a TTL level GPSDO. Can show message data for GPSDO units without displays

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Open Items, Ideas

- Both High and Lo side drivers for relays
- Power, Band In and Band Out, and GPS connectors to PCB edge so they are accessible via the back panel direct, no wire harness
- GPSDO 10Mhz connection – enable homebrew GPSDO function with either 1PPS and/or 10MHz sampling
- Rearrange IO pins better (free up analog capable pins by moving digital signals elsewhere
- Free up UART TX line for full duplex UART
- Move I2C for LCD and future driver chips to native i2c pins
- Optionally Key the Band Out lines with PTT (easy software only change). If transverters are all on, selection is determined by which PTT operates. Assumes antennas are connected full time and no IF switching needed
- Add new driver array with PTT to key output. Needed when Band Out is used for IF and/or antenna selection
- Add new driver array to support separate IF selection and antenna selection patterns
- Remove parallel LCD header, support only I2C.
- Many more for V2 PCB

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Where to find more project info

- Full document on usage, build instructions, Bill of Materials, configuration examples and menu operation
- OneDrive share at https://1drv.ms/u/s!AiKFVkEi7IjLoq0z4Jk7tv5d9ZGrTg?e=ZaoAyH
- Paper published in CSVHFS Annual Conference July 2019 Proceedings

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