

CYD Digital VFO — from bench parts to radio installation.

A detailed guide to assembling, programming, testing, configuring, and safely integrating the ESP32-2432S028R + Si5351 programmable crystal-radio VFO.

Experimental project: This software and the radio profiles are under active development. Verify the calculated and measured oscillator frequency and signal level with test equipment before connecting the Si5351 to a radio. A crystal socket is not automatically a safe direct CMOS input.

1. Scope and project status

The CYD Digital VFO uses an ESP32-2432S028R “Cheap Yellow Display” as the user interface and controller for an Si5351A clock-generator module. The goal is to replace or emulate crystal/channel-element oscillator frequencies used by older crystal-controlled radios, while allowing the operator to enter the desired radio operating frequency directly.

The firmware performs the radio-specific IF and multiplier/divider math, then programs the Si5351 with the oscillator frequency the radio would otherwise obtain from a crystal or channel element.

Bench-tested hardware: ESP32-2432S028R with ST7789 display, XPT2046 resistive touch controller, and Si5351 detected at I²C address `0x60`. Independent CLK0 and CLK2 state and programming have also been tested on the bench.

Not yet RF-certified: A successful firmware calculation or Si5351 programming call does not prove the physical RF output is correct for every installation. Frequency, waveform level, loading, and the radio injection point must still be verified with suitable test equipment.

2. Parts and test equipment

Required project hardware

Item	Requirement / notes
CYD controller	ESP32-2432S028R, 2.8-inch 320×240 resistive-touch version.
Clock generator	Si5351A module, normally using I ² C address <code>0x60</code> .
USB cable	Data-capable USB cable for firmware installation and power during bench setup.
Hookup wiring	Short wiring for power, ground, SDA, SCL, and the selected CLK output(s).
Radio service information	Strongly recommended. You need the oscillator/channel-element circuit, IF, multiplier chain, and operating voltages for the exact model.

Strongly recommended test equipment

- Frequency counter or service monitor covering the expected Si5351 output frequency.
- Oscilloscope with a high-impedance probe; an active probe is helpful around oscillator circuits.
- Digital multimeter for DC bias and continuity checks.
- 50-ohm dummy load rated for the transmitter power when testing TX.
- RF wattmeter / service monitor for transmitter verification.
- Signal generator and SINAD/quieting measurement capability for serious receiver alignment work.

Do not use on-air transmission as the first TX test. Perform transmitter work into a suitable dummy load and verify that the radio is operating on the intended frequency before connecting an antenna.

3. Identify the CYD display variant

Boards sold under the ESP32-2432S028R / “Cheap Yellow Display” name are not guaranteed to contain the same LCD controller.

Variant	Project status	What to do
ST7789	Bench tested	Use the current public Beta 0.3 installer. The current bench unit requires an unusual empirical color mapping that is already built into this firmware.
ILI9341	Compile verified, not bench tested	A separate firmware target now exists, but it should not be treated as verified until tested on actual ILI9341 hardware for orientation, colors, and touch mapping.

If your display remains blank, has incorrect colors, is mirrored, or touch locations do not correspond to the screen, stop and identify the actual LCD/touch hardware before assuming the Si5351 or radio math is at fault.

4. CYD to Si5351 wiring

The current firmware uses these connections:

Function	CYD / ESP32	Si5351 module
I ² C data	GPIO 27	SDA
I ² C clock	GPIO 22	SCL
Ground	GND	GND
Clock output A	—	CLK0
Clock output B	—	CLK2

Power the Si5351 module according to the requirements of the module you actually purchased. Many breakout boards include their own regulator and level shifting; others do not. Check the board documentation before assuming a supply voltage.

Common ground is required between the CYD/Si5351 system and the radio whenever the clock signal is referenced directly to the radio circuitry, unless you intentionally design an isolated RF coupling stage.

5. Assemble and test on the bench first

1

Keep the radio disconnected. Assemble only the CYD, Si5351, USB cable, and test equipment.

2

Wire GPIO27 to SDA, GPIO22 to SCL, and connect a common ground.

3

Connect the Si5351 supply appropriate for your module.

4

Leave CLK0 and CLK2 disconnected from the radio.

5

Install the firmware and confirm the CYD boots normally.

6

Select a known radio profile or Custom Radio setting and enter an operating frequency.

7

Measure CLK0 or CLK2 with a frequency counter or oscilloscope and compare the measured output with the displayed **CALC CLK** value.

8

Do not proceed to the radio until the measured clock is correct and stable.

6. Install the firmware

Browser installer

1

Open the CYD Digital VFO page in a Chromium-based browser such as Chrome or Edge.

2

Connect the CYD with a data-capable USB cable.

3

Choose the current tested ST7789 installer unless you know you have another supported display variant.

4

Click the install button and select the CYD serial port when prompted.

5

Allow the installer to finish before disconnecting USB power.

The current browser package is a complete ESP32 image. A fresh installation may erase existing CYD settings.

Manual binary

The merged Beta 0.3 binary is also available from the project page for users who prefer their own ESP32 flashing workflow.

7. First boot and touch calibration

On first boot, the firmware initializes the display, touch controller, I²C bus, Si5351, saved state, and both clock outputs.

- The ST7789 build uses display rotation 1.
- The XPT2046 touch controller uses its own SPI bus and touch rotation 0.
- Touch calibration is saved in nonvolatile memory.
- If calibration is absent or cleared, follow the on-screen calibration targets carefully.
- The firmware checks for the Si5351 at address `0x60`.

If the display works but the touch locations are wrong, recalibrate touch before troubleshooting the radio or oscillator logic.

8. Using the main interface

Control	Function
Large red frequency	The requested radio operating frequency, not necessarily the physical Si5351 output frequency.
Up / Down arrows	Adjust the selected digit/step of the operating frequency.
DIRECT	Enter an operating frequency directly.
RADIO	Select the radio/profile formula used to calculate the required oscillator frequency.
SIMPLEX / DUPLEX	Choose whether RX and TX use one operating frequency or separate frequencies.
RX EDIT / TX EDIT	In duplex mode, selects which side is being edited.
CLK0 / CLK2	Select which independent Si5351 output/profile state you are viewing and editing.
CAL	Adjust stored oscillator trim in 1, 10, 100, or 1000 Hz steps.

The firmware accepts radio operating frequencies from approximately 1 MHz through 470 MHz, but the physical Si5351 output is guarded to approximately 8 kHz through 160 MHz. The selected radio profile translates operating frequency into the required oscillator frequency.

9. Current radio profiles and crystal math

The following table describes the current Beta 0.3 calculations. **F_o** means the requested radio operating frequency. “RX” and “TX” are the clock frequencies the CYD calculates for the radio oscillator/channel-element path.

Current profile	RX calculation	TX calculation
Mitrek / MSR VHF	$(F_o - 10.7 \text{ MHz}) / 3$	$F_o / 12$
Mitrek / MSR UHF	$(F_o - 10.7 \text{ MHz}) / 9$	$F_o / 36$
MICOR Low Band K1003/4	$(F_o - 5.26 \text{ MHz}) / 3$ in the current preset	$F_o / 6$
MICOR VHF HI	$(F_o + 11.7 \text{ MHz}) / 9$	$F_o / 12$
MICOR VHF LOW	$(F_o - 11.7 \text{ MHz}) / 9$	$F_o / 12$
MICOR 220 modification	$(F_o - 11.7 \text{ MHz}) / 12$	$F_o / 18$
GE MASTR II VHF	$(F_o - 11.2 \text{ MHz}) / 9$	$F_o / 12$
GE MASTR II VHF high-side	$(F_o + 11.2 \text{ MHz}) / 9$	$F_o / 12$
GE MASTR II UHF	$(F_o - 11.2 \text{ MHz}) / 27$	$F_o / 36$
GE MASTR II UHF high-side	$(F_o + 11.2 \text{ MHz}) / 27$	$F_o / 36$
GE Executive II VHF	$(F_o - 11.2 \text{ MHz}) / 9$	$F_o / 12$
GE Executive II UHF	$(F_o - 11.2 \text{ MHz}) / 27$	$F_o / 36$
GE MVP VHF	$(F_o - 11.2 \text{ MHz}) / 9$	$F_o / 12$
GE MVP UHF	$(F_o - 11.2 \text{ MHz}) / 27$	$F_o / 36$
GE Delta VHF	$(F_o - 10.7 \text{ MHz}) / 3$	$F_o / 3$
GE Delta UHF	$(F_o - 10.8 \text{ MHz}) / 9$	$F_o / 9$
GE Phoenix VHF	$(F_o - 10.7 \text{ MHz}) / 3$	$F_o / 3$
GE Phoenix UHF	$(F_o - 21.4 \text{ MHz}) / 9$	$F_o / 9$
Maxon DM-0530	$(F_o - 21.4 \text{ MHz}) / 9$	$F_o / 27$
MAXAR / FLEXAR VHF	$(F_o - 10.7 \text{ MHz}) / 3$	$F_o / 9$
MAXAR / FLEXAR UHF	$(F_o - 10.7 \text{ MHz}) / 9$	$F_o / 27$

Important: This table documents what the current firmware implements. Some radio families contain multiple band splits, oscillator arrangements, or special mobile/station versions. Always compare the selected profile with the service information for the exact radio before connecting it.

10. Custom Radio calculator

Custom Radio mode is for a radio that is not yet in the preset database or for an experiment that requires a different IF/injection relationship.

The Custom screen provides:

- Operating frequency.
- IF / offset entry in MHz.
- Multiplier/divisor entry.
- High-side or low-side injection selection.
- Separate RX and TX plans in duplex mode.
- A live **CALC CLK** result before saving.

Typical formula

For a conventional low-side receiver where the radio multiplies the crystal oscillator by **N** before mixing:

$$\text{CLK} = (\text{Operating Frequency} - \text{IF}) / N$$

For high-side injection:

$$\text{CLK} = (\text{Operating Frequency} + \text{IF}) / N$$

For a transmitter where the crystal frequency is multiplied directly:

$$\text{CLK} = \text{Operating Frequency} / N$$

Do not guess the IF or multiplier. Obtain them from the radio service manual, channel-element documentation, a known crystal frequency, or a verified measurement.

11. Using CLK0 and CLK2

CLK0 and CLK2 are intentionally independent. Each clock can retain its own:



Radio profile



RX and TX frequencies



Simplex / duplex state



RX/TX edit state



Calibration trim



Custom Radio math

This allows one CYD/Si5351 assembly to support experiments such as separate receive/transmit oscillator paths, two radios, or two independent channel-element functions.

The fact that both clock outputs can be programmed independently does not mean a particular radio wants two independent oscillator sources. Determine the radio architecture first.

12. Prepare the radio before connecting the CYD

- 1 Obtain the service manual or schematic for the exact radio model and band split.
- 2 Identify whether RX and TX use separate crystals/channel elements or share one oscillator architecture.
- 3 Record the original crystal/channel-element number and marked frequency if present.
- 4 Determine the radio's IF and multiplication chain from the service information.
- 5 Measure DC voltage at the intended oscillator connection point with the original hardware installed and then removed, if safe to do so.
- 6 Measure the original oscillator signal with a high-impedance probe when possible. Record approximate frequency and amplitude.
- 7 Verify the CYD calculation independently by hand before making a connection.

This preparation is especially important on Motorola channel-element radios because two radios that look similar externally can use different oscillator architectures.

13. Find the correct oscillator/injection point

The safe connection point is not simply “where the crystal was” in every radio. A channel element may contain an oscillator transistor, temperature compensation, modulation circuitry, or buffering in addition to the crystal itself.

What you are trying to locate

Ideally, inject the synthesized clock at a point that normally carries the oscillator signal **after** the crystal-controlled oscillator stage but **before** the multiplier/mixer chain. That often lets the radio keep its designed buffering and multiplication stages while removing the need for the crystal resonance itself.

Questions to answer from the schematic

- Is the crystal connected directly in a transistor oscillator?
- Does the channel element output a buffered RF signal to the radio?
- Is modulation applied by pulling the crystal/oscillator frequency?
- Does the oscillator node carry DC bias?
- What impedance/load did the original oscillator expect to drive?
- Is the radio using low-side or high-side injection?

Never assume the Si5351 pin can tolerate radio DC bias. If the radio oscillator point carries DC, use appropriate AC coupling and design the interface so DC cannot be driven back into the Si5351 output.

14. Signal level and conditioning

The Si5351 produces a digital clock waveform. A crystal oscillator or channel element may have produced a much smaller, approximately sinusoidal RF signal. Direct connection can therefore overdrive the radio, disturb bias conditions, create extra harmonics, or damage the Si5351 if the radio feeds DC back into the output.

Possible interface elements

- **Series resistor:** useful for limiting drive and reducing ringing.
- **AC-coupling capacitor:** blocks DC between the radio oscillator node and the Si5351.
- **Resistive attenuator:** reduces a strong CMOS clock to a level closer to the original oscillator.
- **Buffer stage:** isolates the Si5351 from an unknown or heavily loaded radio node.
- **Low-pass or band-pass filtering:** may reduce square-wave harmonics where appropriate.

There is no universal resistor/capacitor/attenuator value for every radio. Choose the interface based on the measured original signal, the service schematic, and the oscillator node impedance.

Best practice: start with the synthesized signal disconnected from the radio, measure it, then connect through a conservative coupling/attenuation arrangement and verify operation before increasing drive.

15. Receiver installation and test

- 1 Select the correct receiver profile or enter the verified Custom Radio formula.
- 2 Set the desired receive operating frequency.
- 3 Confirm the displayed calculated CLK frequency by hand.
- 4 Measure the physical Si5351 output before connecting the radio.
- 5 Connect the clock through the planned coupling/interface network.
- 6 Power the radio and confirm that the receiver behaves normally.
- 7 Inject a known RF test signal at the desired operating frequency.
- 8 Verify sensitivity, quieting/SINAD, and alignment. Do not judge success only by hearing a strong local signal.
- 9 If receiver sensitivity is poor, verify oscillator level, mixer injection, front-end alignment, and image/injection-side assumptions.

16. Transmitter installation and test

- 1 Connect the transmitter to a correctly rated 50-ohm dummy load.

- 2 Select the correct TX profile and desired operating frequency.
- 3 Measure the Si5351 clock frequency before connecting it to the radio.
- 4 Connect the clock using the appropriate coupling/conditioning network.
- 5 Key the transmitter only briefly at first.
- 6 Verify final carrier frequency with a frequency counter/service monitor.
- 7 Check transmitter power, current, spectral cleanliness, and modulation/deviation as appropriate for the radio.
- 8 Confirm that changing RX settings cannot unintentionally move TX to an unsafe frequency.

Frequency correctness is only one requirement. A transmitter can be on frequency and still have improper drive, spurious outputs, incorrect deviation, or poor multiplier tuning after a large frequency change.

17. Duplex and repeater installations

Duplex mode stores independent RX and TX operating frequencies. Use **RX EDIT** and **TX EDIT** to configure each side.

For radios with separate RX and TX channel elements, CLK0 and CLK2 may be useful as independent sources. For radios that derive both paths from one channel element or use an offset oscillator, the architecture may require a different approach.

Examples of architecture differences

- Some station/repeater radios use physically separate receive and transmit channel elements.
- Some mobile radios use one channel element plus an offset oscillator to derive transmit from receive.
- Some radios expect crystal pulling for FM modulation, while others apply modulation later in the chain.

Do not force a two-clock installation onto a radio that was designed around one oscillator/offset architecture without understanding the consequences.

18. Final validation checklist

✓ Correct CYD display variant selected

✓ Touch calibration accurate

✓ Si5351 detected at 0x60

✓ Hand calculation matches CALC CLK

✓ Measured CLK matches calculated CLK

✓ Radio service manual matches selected profile

✓ DC bias isolated from Si5351 if required

✓ Clock amplitude appropriate for injection point

✓ Receiver sensitivity verified

✓ TX tested into dummy load

✓ TX carrier frequency verified

✓ Modulation/deviation verified

✓ No unintended CLK0/CLK2 interaction

✓ Power wiring and grounds secure

19. Troubleshooting

Symptom	Check first
Blank or scrambled CYD display	Confirm ST7789 vs ILI9341 variant and correct firmware build.
Touch is offset or reversed	Clear/re-run touch calibration; verify display/touch variant.
Si5351 not found	Power, ground, GPIO27 SDA, GPIO22 SCL, and I ² C address 0x60.
CALC CLK says invalid / output disabled	The calculated oscillator frequency is outside the firmware's supported Si5351 range or the profile input is invalid.
Frequency counter shows wrong value	Confirm correct CLK output, profile, RX/TX edit state, and calibration trim.
Radio receives but sensitivity is poor	Wrong injection side, inadequate/excessive oscillator level, front-end alignment, or loading of oscillator/mixer node.
TX is off frequency	Wrong multiplier/profile, wrong TX edit frequency, trim error, or radio multiplier chain not aligned.
TX power is low after frequency change	Multiplier/exciter/final stages may require alignment for the new frequency; do not assume the oscillator is the only tuned circuit.

Radio works on RX but not TX	Many radios use separate RX and TX oscillator paths. Confirm the TX channel element architecture and source.
Unexpected spurs or noise	Clock level too high, square-wave harmonics, grounding, long wiring, poor shielding, or insufficient filtering/isolation.

20. Report your results and help improve the project

This project is intentionally being released while it is still growing. Real bench results are valuable because they tell us which radio profiles work as expected, which models need different formulas, which display variants need support, and where the instructions need improvement.

Please submit the radio model, band/frequency, selected profile, CLK output, what worked, what did not, and any measurements you made.

Future versions are expected to expand the verified radio database, improve display-variant coverage, and incorporate issues and feature requests reported by testers.