

RCSIM Tier 0 — Audio PPM (Zero Hardware): User Manual

Illustrated user guide: configuration cards, deployment actions and step-by-step procedures. The screenshots show the English interface.

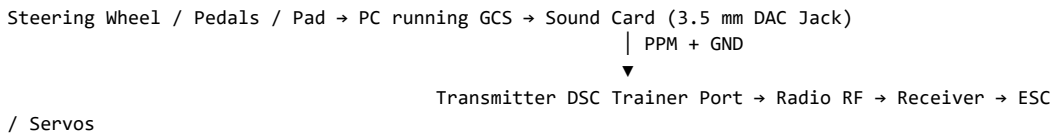
Contents

1. What Tier 0 Does	2
2. Software Architecture and Audio Pipeline	2
3. Hardware Requirements and Electrical Connections	3
3.1. 3.5 mm Jack Cable Pinout	3
3.2. Voltage Levels: USB DAC vs Integrated Realtek	3
4. RCSIM GCS Configuration	3
5. Transmitter Configuration (EdgeTX / OpenTX)	4
6. First Run and Safety Verification	4
7. Diagnostics and Troubleshooting	4
8. Source Code Verification Trails	5

Edition: 14 October 2026. This manual covers generating PPM signals directly from a PC sound card output (3.5 mm audio jack) into the trainer (DSC) port of an RC transmitter. The documentation is grounded in the GCS codebase and measured electrical parameters of the audio path.

1. What Tier 0 Does

Tier 0 ("Zero Hardware") allows an operator to drive an RC model using standard sim-racing gear (steering wheels, pedals, gamepads) connected to a PC, without requiring any dedicated microcontroller bridge (Arduino, RP2350). The PC synthesizes the PPM pulse train directly via the sound card's Digital-to-Analog Converter (DAC).



The signal from the headphone/line-out jack travels through a standard 3.5 mm mini-jack cable into the radio's trainer input (e.g. RadioMaster MT12, TX16S, Boxer, FlySky, FrSky). The radio decodes the channels in Trainer mode and transmits them wirelessly via its internal RF module to the vehicle receiver.

Tier 0 strictly transmits control channels (PPM). FPV video and reverse telemetry require completely independent signal paths (e.g. an analogue/digital FPV receiver connected via HDMI/USB grabber to the PC).

2. Software Architecture and Audio Pipeline

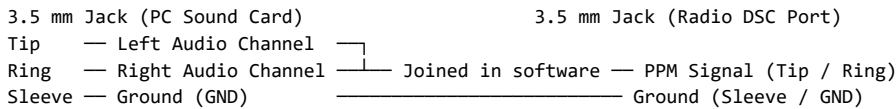
Signal generation is implemented in GCS by `AudioPPMStrategy` and `PPMWaveformGenerator` under `core/comm/`.

- **Sample Rate:** Default **192,000 Hz** (96,000 Hz and 48,000 Hz also supported). The high sample rate minimizes pulse edge jitter to below 5 μ s.
- **Channel Count:** 1 to 16 channels (default **8 channels**).
- **Frame Duration** (`frame_length_ms`): Default **22.5 ms**. If channel count increases, the generator automatically extends the frame to preserve a safe sync gap (> 4.0 ms).
- **Sync Pulse Width** (`sync_pulse_us`): Default **500 μ s** (range 300–800 μ s). A pulse width of 500–600 μ s is essential to charge the RC low-pass filter on the radio's DSC input.
- **Polarity** (`audio_ppm_polarity`): **NEGATIVE** or **POSITIVE**.
- **Double Buffering (Zero Phase Tearing):** The 100 Hz control loop never modifies the audio buffer during playback. Channel updates are strictly latched on the PPM frame boundary (`pos == 0`), preventing phase tearing and pulse loss in the EdgeTX decoder.
- **Continuous Carrier (No Carrier Loss):** In the **DISARMED** state, audio output is never muted to 0.0V. The generator continuously transmits neutral frames (1500 μ s on all channels). This eliminates EdgeTX "Trainer signal lost" alarms and haptic buzz before launch.
- **Stereo Tip + Ring Duplication:** The PPM waveform is duplicated identically across both left and right audio channels, ensuring 100% electrical compatibility with both mono and stereo cables/sockets.

3. Hardware Requirements and Electrical Connections

3.1. 3.5 mm Jack Cable Pinout

A male-to-male 3.5 mm mini-jack cable is used to connect the PC audio output to the transmitter's DSC/Trainer port.



Because GCS mirrors the waveform onto both Tip and Ring, a stereo cable works reliably even if the radio socket is physically wired as mono.

3.2. Voltage Levels: USB DAC vs Integrated Realtek

PC sound card output amplitude is typically 1.0–2.2 V Pk-Pk. The logical high threshold V_{IH} of radio microcontrollers is usually ~1.8–2.0 V.

- **Integrated Motherboard Realtek Audio:** Motherboard jacks often feature output coupling capacitors causing voltage sag under load, as well as negative undershoot. This can cause intermittent trainer detection (the radio sees the trainer for a split second, then drops out).
- **External USB DAC Adapters:** Inexpensive USB sound cards (or USB headphone dongles such as the Corsair HS60 PRO) deliver clean 2.0–2.5 V output rails free from motherboard ground noise, ensuring instant, rock-solid decoding in EdgeTX.
- **Polarity and AC Coupling:** Audio outputs are AC-coupled. Setting polarity to POSITIVE (and POS in EdgeTX) keeps the resting voltage close to 0V and outputs positive voltage spikes, preventing diode clipping in the transmitter's ESD protection circuit.

4. RCSIM GCS Configuration

1. Connect your steering wheel/pedals to the PC and the 3.5 mm audio cable between the PC and the radio.
2. Launch GCS and navigate to **Configuration** → **Connection Settings**.
3. In the **GCS Mode** dropdown, select **Audio PPM (Trainer Port)**.
4. On the **Tier 0 / Audio PPM** card, configure:
 - **Audio Output Device:** Select the target sound card (e.g. USB DAC Headphone Out).
 - **Sample Rate:** Select **192000 Hz** (or the highest stable rate supported).
 - **Channels Count:** Set to **8**.
 - **Frame Length:** Set to **22.5 ms**.
 - **Sync Pulse Width:** Set to **500 µs** (increase to 600 µs if signal detection is inconsistent).
 - **Signal Polarity:** Set to **POSITIVE** (matching the radio configuration).
 - **Output Volume / Amplitude:** Set to **1.0** (100% master volume in Windows for this endpoint).
5. Open **Channel Definitions** and **Control Mapping** to map your wheel and pedals to channels CH1–CH8.
6. Return to **Cockpit**, select **Manual (Driver)** mode, and click **Connect**.
7. Use the diagnostic option **Test Center (1500 µs)** to output a calibrated neutral stream.
8. Click **ARM SYSTEM** to enable the active audio modulation.

5. Transmitter Configuration (EdgeTX / OpenTX)

Configuration procedure for EdgeTX radios (RadioMaster MT12, Boxer, TX16S, Pocket):

1. Model Setup:

- Navigate to **MDL** → **Model Setup**.
- Scroll to the **Trainer** section.
- Set **Mode**: Master / Jack.
- Set input format: PPM, polarity: POS (matching GCS), and frame: 22.5ms 500us.

2. Trainer Activation (Special Functions):

- Open **MDL** → **Special Functions**.
- Create a new function assigned to a physical toggle switch on the radio.
- Action: **Trainer**, parameter: **Sticks** (or channels 1–8).
- Check the **ON** enable box.

3. Channel Monitor Inspection:

- Open the **Channel Monitor** screen on the transmitter.
- Flip the Trainer switch. Channel bars should immediately reflect the values sent by GCS.
- Turn the wheel and press the pedals — bars must track inputs smoothly.

6. First Run and Safety Verification

1. **Model Safeguarding:** Before powering the vehicle, remove the wheels, place the chassis on a stand, or disconnect motor wires from the ESC.

2. Power-On Sequence:

- Power on the RC radio and verify RF binding with the vehicle receiver.
- Plug the 3.5 mm audio cable into the PC and transmitter.
- In GCS, connect the Audio PPM profile and click **ARM SYSTEM**.
- Verify channel motion on the transmitter monitor.
- Only after confirming a solid 1500 µs center and correct directions should you power the vehicle ESC.

3. Cable Disconnect Test (Trainer Failsafe):

- While the model is disarmed on the bench, unplug the 3.5 mm cable from the radio.
- The transmitter must immediately indicate trainer signal loss and revert to internal sticks or trigger its programmed failsafe.
- Verify that the motor does not spin up unexpectedly.

7. Diagnostics and Troubleshooting

- **Radio announces "Trainer signal lost" and vibrates:**
- Verify that the Windows audio device is unmuted and set to 100% volume.
- Disable all audio enhancements (Spatial Audio, Sonic, Dolby, EQ).
- Increase sync_pulse_us from 500 µs to 600 µs.

- Switch polarity in both GCS and radio from NEGATIVE to POSITIVE.
- Use an external USB DAC instead of the integrated Realtek motherboard output.
- **Trainer signal appears briefly then drops:**
- AC coupling capacitors in the sound card are discharging during long pulse intervals. Use POSITIVE polarity and ensure the continuous carrier feature is active.
- **Jittery or fluctuating channel values:**
- Verify 192,000 Hz sample rate in both GCS and Windows Sound Control Panel (Properties → Advanced → Default Format: 24-bit/192000 Hz).
- Inspect the 3.5 mm cable and socket for loose contacts.
- **Bars move on radio, but vehicle does not respond:**
- Check the radio mixer (**MIXES** tab) — trainer inputs (TR1–TR8) must be assigned to output channels (CH1–CH8).

8. Source Code Verification Trails

- `RCSIM_PC/pc_app/core/comm/audio_ppm_strategy.py` — strategy implementation, sounddevice streaming, float32 double buffering, continuous carrier.
- `RCSIM_PC/pc_app/core/comm/ppm_waveform_generator.py` — PPM pulse synthesis, 22.5 ms frame timing, 500 µs sync pulse width, polarity control.
- `RCSIM_PC/pc_app/core/comm_manager.py` — AUDIO_PPM strategy registration.
- `RCSIM_PC/pc_app/gui/tabs/connection_sections.py` — GCS UI sound card configuration parameters.