Sony XDR-F1HD

The XDR-F1HD is Sony's first home HD Radio tuner. It receives all AM and FM HD Radio modes, including multicasts, as well as analog AM and FM.

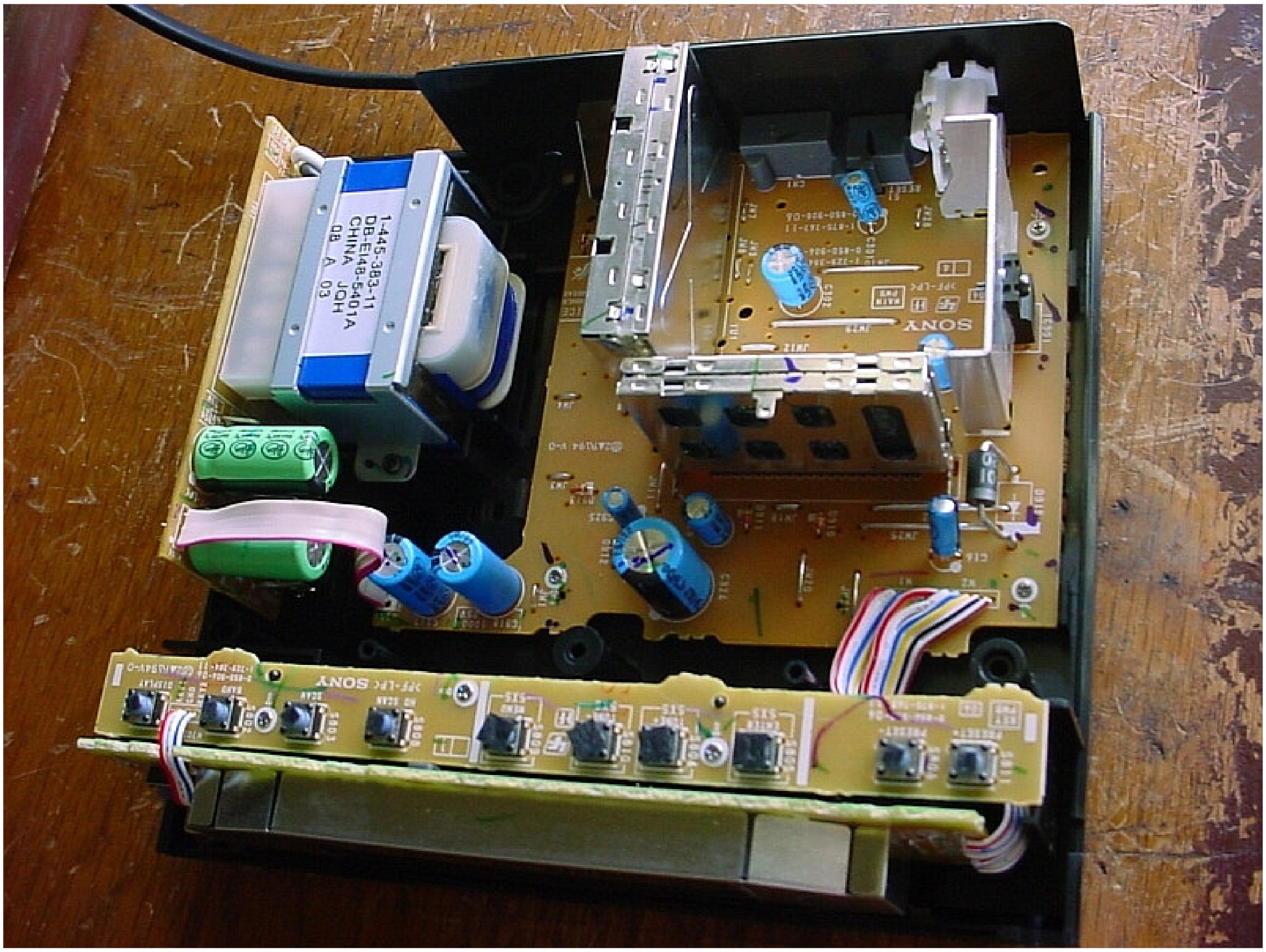
At 7⅛″ × 6⅜″ × 2⅜″, the tuner is much smaller than standard stereo components. It weighs less than 2½ lbs. The FM antenna input is a 75Ω F-connector, while spring-loaded AM terminals accept wires. The tuner comes with an AM loop and an FM dipole. RCA jacks provide analog audio. The captive two-wire line cord has a polarized plug. Rated power consumption is 13 watts.

The front panel has a power button and LCD, while the top surface has ten control buttons. The rear panel has a recessed reset button. The tuner includes an infrared remote control. It requires two AAA batteries, not supplied.

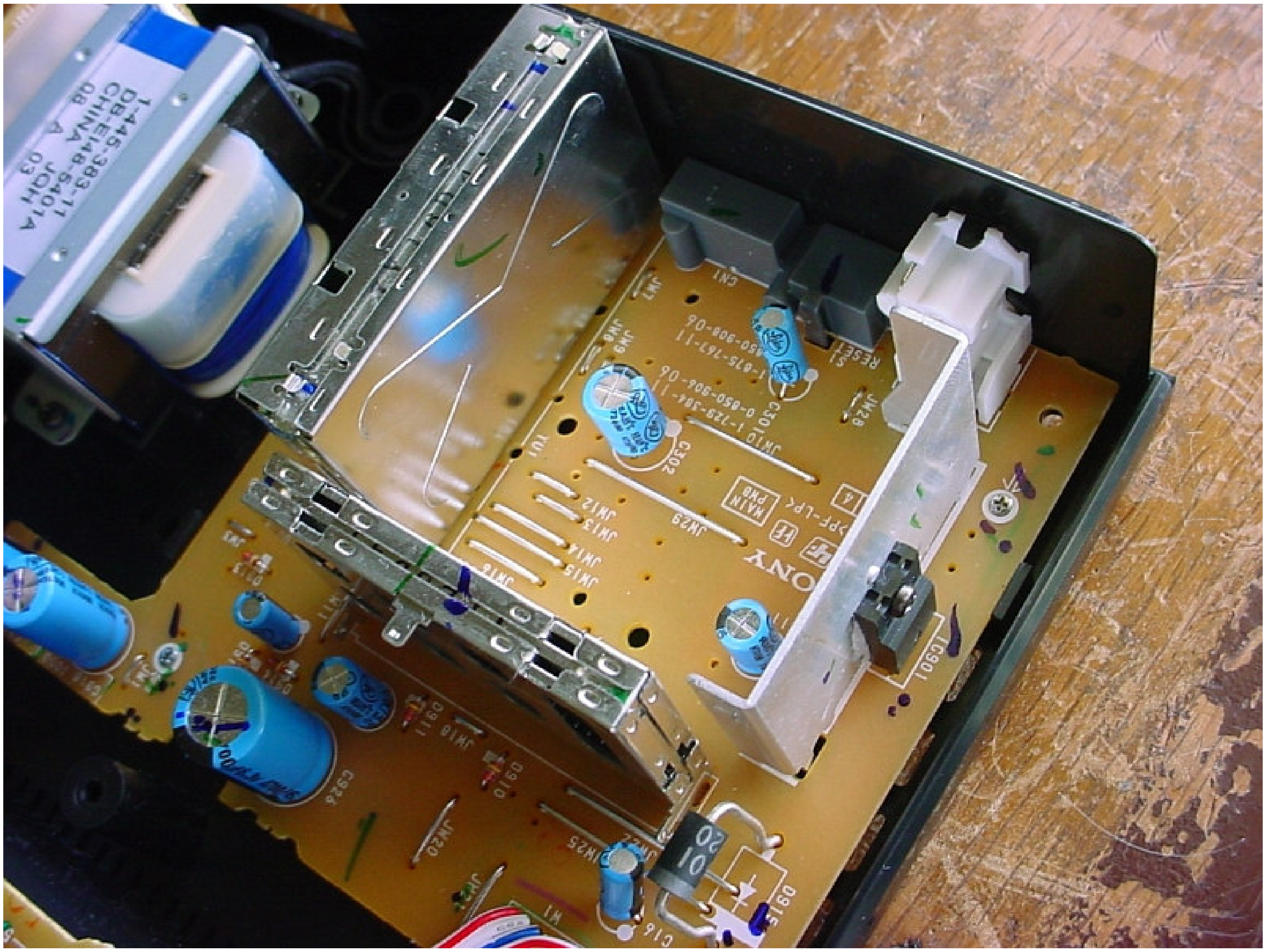
The cabinet is made of rigid plastic. Perforated vents cover much of the bottom and the upper rear panel. Louvered vents span the top surface at the rear.

This compares the size of the XDR-F1HD with that of the Sangean [HDT-1X](). U.S. design patent D598,892 S covers the Sony's ornamental design.

Under the Hood



Five screws retain the top cover, which easily comes off. Inside is a power board, main motherboard, display board, and pushbutton board. The power board delivers unregulated +5.2V and +10.5V. Its five rectifiers are bypassed, which suppresses interference on AM. Directly above the rectifiers are two green electrolytics rated at 105° C. In parallel on the motherboard below are two blue electrolytics rated at 85° C with about half the capacitance. The underside of the motherboard has surface-mount parts, including six voltage regulators. The system controller is on the display board. All boards are well marked, with components, signals, voltages, and test points identified. No adjustments are visible.



Mounted vertically on the motherboard is a seventh voltage regulator on a heatsink and two shielded modules. The tuner module is next to the power transformer, which was still too hot to touch ten minutes after removing the cover. The silkscreen identifies both pins of the transformer's internal fusible link. Should the link ever fail due to a temporary fault, you can install an external fuse. The other module is the HD Radio processor. Two snap-on shields are soldered to the tuner module at its upper corners. Unsolder the shield facing the heatsink and inside you'll find the NXP TEF6730/SAF7730 chipset and several adjustments. The HD module contains an SAF3550 and a 16MB SDRAM.

On the underside of the top cover is a curious bare PC board attached with screws and adhesive. A small square of plastic film insulates contact with the tuner module. The board is marked SHIKIRI PWB. *Shikiri* means partition, division, boundary, or compartment. It is also the ritual where sumo wrestlers down on their fists glare fiercely at each other before a match begins. Surely one of these definitions provides insight.

Features

The XDR-F1HD tunes in 100-kHz steps on FM and 10-kHz steps on AM with the TUNE + and TUNE – buttons. SCAN scans the band in 200-kHz steps on FM and 10-kHz steps on AM (up only). The tuner pauses for three seconds at each signal found. Pressing just about any button halts the scan. HD SCAN excludes analog signals.

The tuner provides 20 presets on FM and 20 on AM. PRESET + and PRESET – sequentially tune them.

The TUNE buttons, also labeled SELECT, select an HD Radio multicast channel. A thoughtful feature is the small display arrow that tells whether another channel exists. No need to risk blowing HD lock checking for HD-3.

A signal-strength indicator shows zero to three bars. Successive bars appear at RF signal levels of 19, 29, and 38 dBf.

The tuner has a clock that resets if the unit is left unplugged for more than five minutes. The presets behave the same way.

MENU lets you set the clock, display contrast, and display brightness. DISPLAY switches between screens that show frequency or time. For RDS or HD Radio a third screen fills with transmit text that only scrolls across a small window in the other screens. The tuner does not display the callsign encoded in the RDS PI field. That would greatly benefit DXing, as it does in the Sangean HDT-1X.

Compared to the HDT-1X, the XDR-F1HD does not display carrier-to-noise ratio, HD Radio transmission mode, HD Radio station ID, firmware version, or the audio spectrum. It does not provide forced mono, forced analog, split-audio mode, direct frequency entry, or digital output. It does not have a stereo indicator and it does not receive C-QUAM AM stereo.

The Sony remote control has a sleep timer the Sangean lacks. It also provides random preset access and a dedicated button for display brightness.

Operating instructions are here. A service manual is here.

Analog FM

The XDR-F1HD uses advanced digital signal processing algorithms to dramatically improve reception of FM signals corrupted by noise and interference.

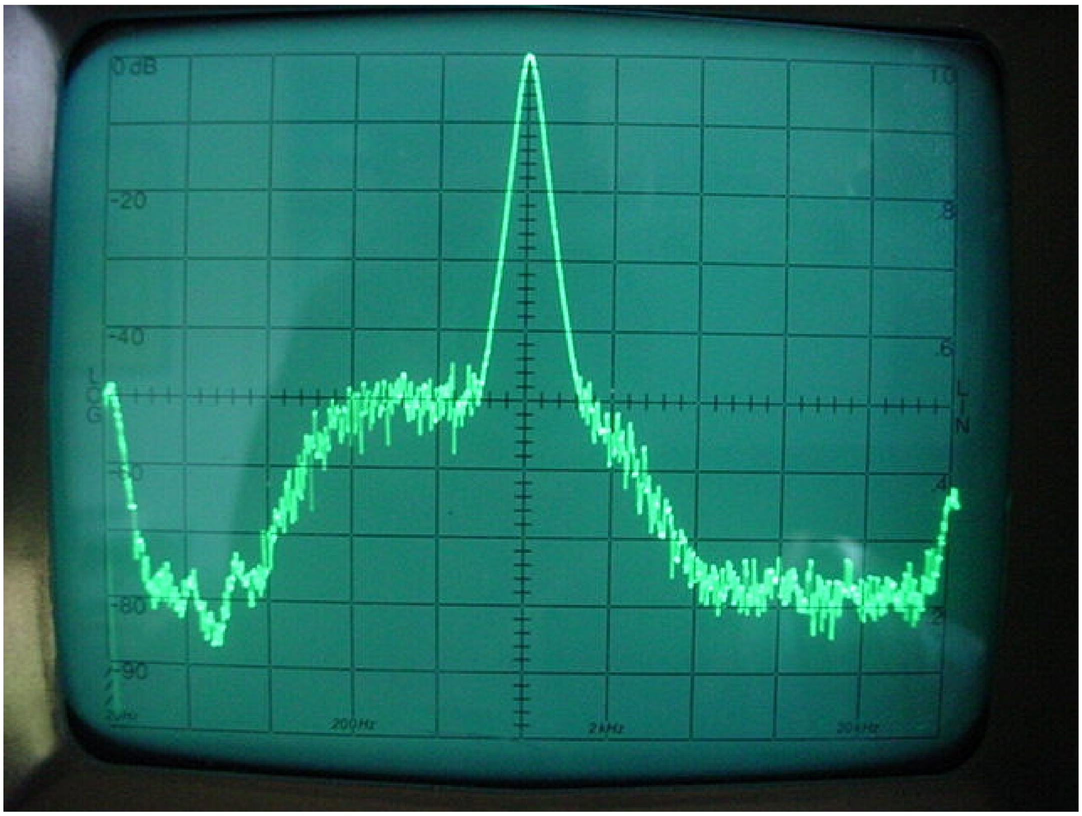
Threshold extension suppresses the impulse noise ordinary FM detectors generate for weak signals. The obtrusive character of this noise quickly degrades reception quality as the signal level falls below a threshold. The impulses arise from detection-vector phase reversal due to additive noise peaks. High-performance satellite and terrestrial microwave FM links have long used various threshold extension techniques to enhance performance. Tracking filter detectors that may extend the threshold occasionally have appeared in consumer FM broadcast tuners.

Adaptive noise reduction forms a filter that tracks the spectrum of the L–R stereo signal. The filter suppresses noise between and beyond spectral peaks without restricting program bandwidth. It also suppresses co-channel interference and multipath distortion, factors that can limit reception quality for stronger signals. The technique takes a big bite out of the 23-dB S/N penalty that has always bedeviled FM stereo reception. Remastered legacy recordings use adaptive noise reduction to suppress surface noise and tape hiss. This may be the technique's first appearance in consumer audio equipment.

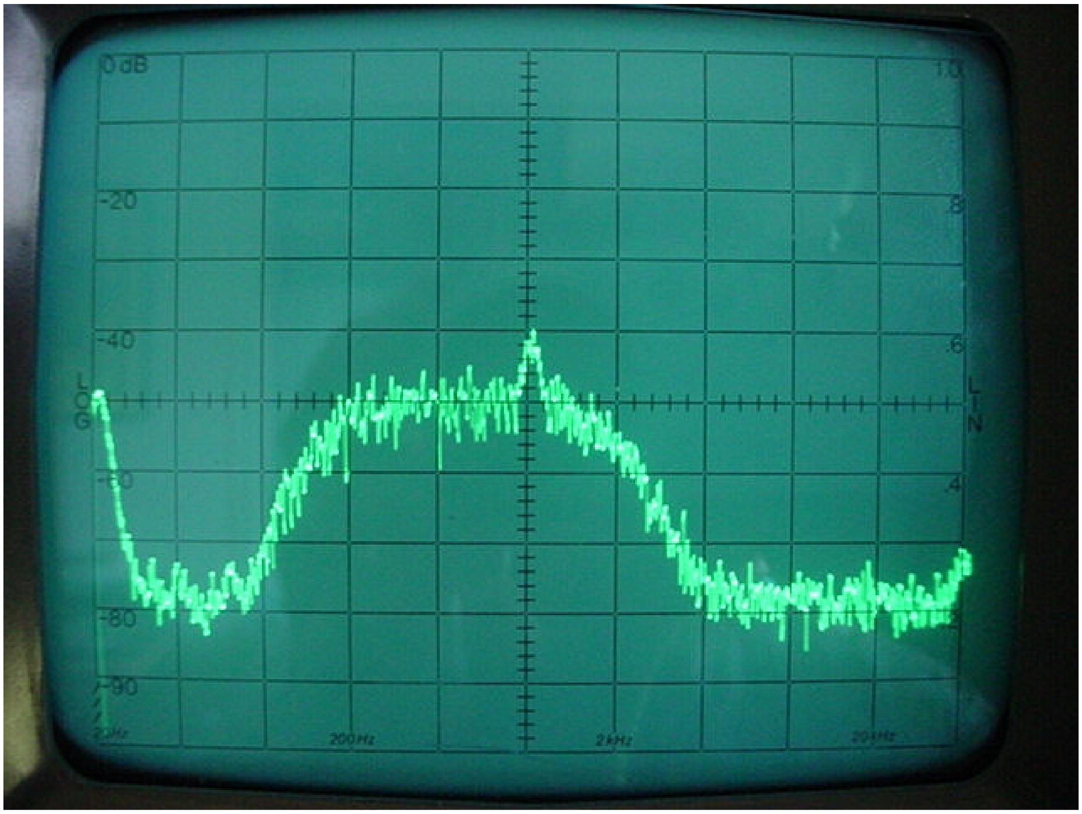
Adaptive digital IF filters eliminate adjacent-channel interference in nearly all cases. The filters have flat passbands with extremely steep skirts. The DSP rapidly swaps filter coefficient sets while retaining state variables to dynamically adapt the filter bandwidth to modulation level and interference without introducing switching artifacts. The digital filters are much more effective than conventional analog IF filters. In addition, they do not have the unit-to-unit variation that necessitates ceramic filter selection or tuned compensation for optimal performance. Finally, their symmetrical finite impulse response eliminates the group delay error that causes audio distortion in analog filters.

To fully benefit from the processing, the XDR-F1HD does not switch or abruptly blend to mono at low RF signal levels. The Sony can deliver a clean stereo signal with wide channel separation at far weaker signal levels than can any other tuner. Only a Carver tuner with ACCD (and perhaps a Pioneer F-93) is remotely comparable.

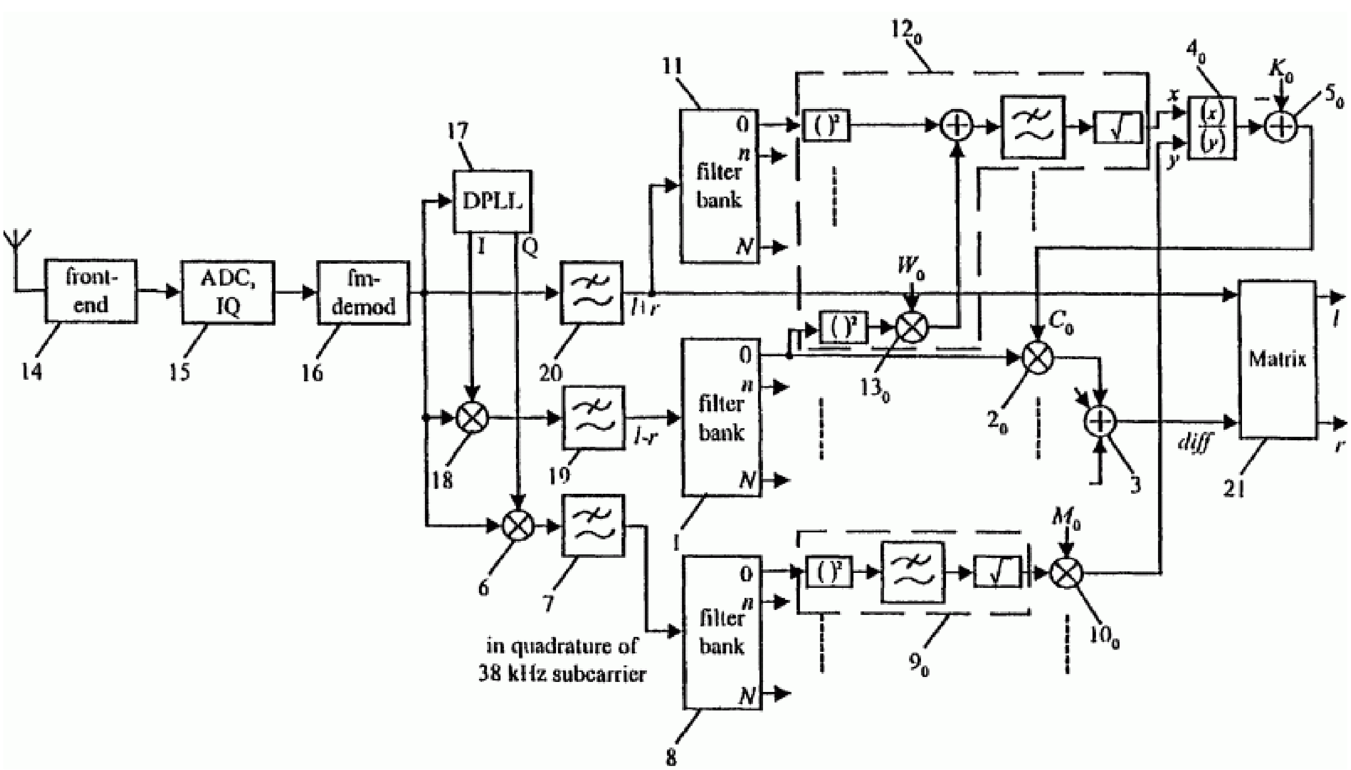
Sound quality for slightly impaired to deeply compromised signals is strikingly better than that from conventional tuners. The performance of the Sony XDR-F1HD on FM stereo is spectacular and unprecedented.



This shows the audio spectrum for a 1-kHz right-channel tone at an RF level of 22 dBf. The horizontal scale is 200 Hz/div and vertical is 10 dB/div. The shape of the adaptive filter is evident from the noise hump.

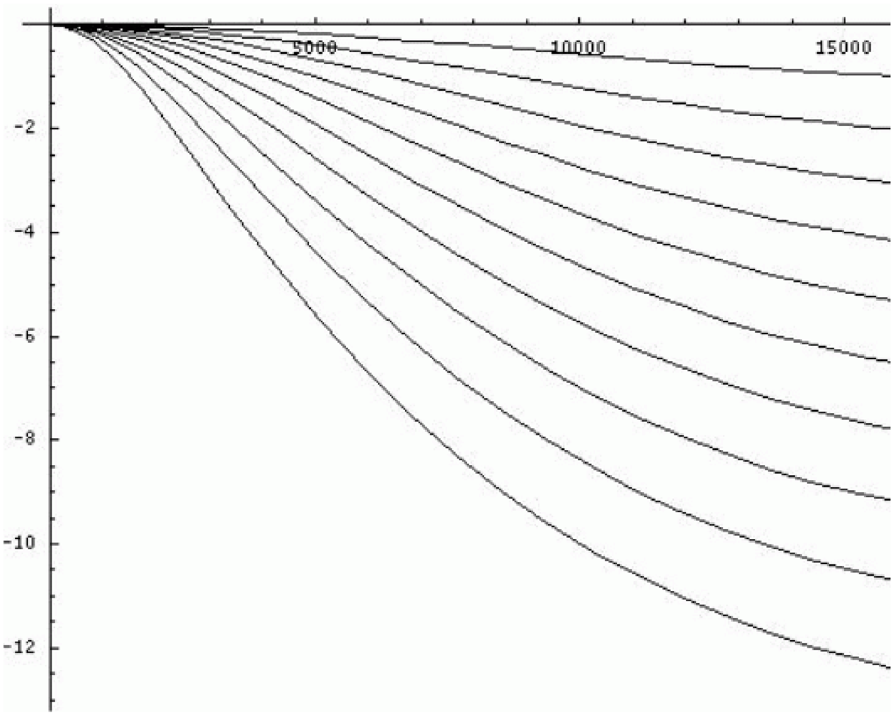


This is the left-channel response. The noise has a pronounced narrowband sound quality. The tone frequency determines the position and bandwidth of the noise hump. Multiple tones cause multiple humps, and a complex signal spectrum acquires a filter adapted to its specific shape. Exploration with a sine wave reveals that the noise reduction algorithm uses a discrete frequency-domain filter bank rather than a continuous time-domain technique. I counted 17 filter passbands.



Adaptive noise reduction affects only the noisy L–R stereo subchannel. The algorithm attenuates filter bank outputs according to critical-band auditory masking criteria. U.S. patent 7,110,549 describes the method, while 7,292,694 refines it. The quadrature L–R signal normally provides a robust estimate of the background noise level in each bank.

The noise reduction algorithm is remarkably well behaved with surprisingly few artifacts. For very noisy signals otherwise unlistenable, low-level L–R noise occasionally may be audible, either emerging from a quiet background from time to time or as a roughness accompanying softer sounds. I noticed another artifact when a station lost one stereo channel. With my balance control set all the way to the unmodulated channel and the volume turned up, I could hear high-frequency sounds reminiscent of aliasing at very low levels. Acoustic image displacement may occur, but usually only for lower-level sounds in very noisy signals. For strong, interference-free signals I cannot distinguish the sound of the XDR-F1HD from that of a conventional tuner, except that the Sony will suppress an occasional sibilant splash due to a touch of multipath.



In addition to the adaptive noise reduction on L–R, the XDR-F1HD gradually applies a high-cut noise filter to L and R when the RF level drops below 26.5 dBf. The filter progressively affects lower frequencies as the signal level falls, as shown above. It is similar to the high-cut filter in the HDT-1X.

While the high-cut response is still dropping, a soft-muting function begins to gradually attenuate the level of the entire spectrum. With no signal the residual noise is down 30 dB from 100% 1-kHz modulation.

For the following measurements I used IEEE 185-1975, updated as described here. I used the test equipment listed here. The figures are for an unmodified, factory-aligned tuner.

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50-dB quieting sensitivity, mono    13.5 dBf
50-dB quieting sensitivity, stereo  13.5 dBf
THD, 1 kHz, mono                    0.07%
THD, 1 kHz, stereo                  0.055%
Stereo separation, 1 kHz            54 dB
S/N, 65 dBf, mono                   70 dB
S/N, 65 dBf, stereo                 68 dB
Capture ratio, 30 dB                1.1 dB
Capture ratio, 50 dB                8.4 dB
Capture ratio, stereo, 30 dB        1.3 dB
Capture ratio, stereo, 50 dB        13.5 dB
AM suppression ratio                80 dB
Adjacent-channel selectivity        82 dB     (noise limited)
RF intermod                         89 dBf    (97.7 + 98.5 -> 96.9)
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RF spur	96 dBf (96.24 -> 96.9)
RF image	87.5 dBf (118.3 -> 96.9)
RF AGC threshold	87 dBf
RF mismatch loss	0.7–2.1 dB
Modulation acceptance, 1 kHz	200%
Modulation acceptance, 20 Hz	76%
Minimum stereo pilot injection	3.5%
Treble response, mono	+0.0/-2.2 dB
Treble response, stereo	+0.0/-1.3 dB
Bass response, -1 dB	21 Hz
Output level	0.7V
Output impedance	2.2kΩ
Audio latency	27 ms
Power-on delay	6 sec
Power consumption, operating	11 W
Power consumption, standby	2 W

The XDR-F1HD has the best sensitivity figures I've ever measured. In mono this is due partly to the threshold extension and partly to the high-cut filter, not to a low noise figure. The input signal drives a transient suppressor, bandpass filter, PIN diode attenuator, single-tuned circuit, and finally the TEF6730 mixer. The tuner does not use an RF amplifier stage. After aligning the front-end, I measured a noise figure of 7.0 dB at 96.9 MHz. A low-noise RF preamp can noticeably improve sensitivity.

The stereo sensitivity figure is not a typo. Noise is 50 dB down for an unmodulated 13.5-dBf stereo signal. This figure is more than 20 dB better than that of conventional tuners. Channel separation is still 26 dB at this signal level. Background noise near the tone frequency does rise with modulation, as shown in the previous images, and a single tone does not entirely mask it. A standard stereo sensitivity test really isn't appropriate for a tuner with adaptive noise reduction. Still, in everyday use stereo reception of weak broadcast signals is an order of magnitude better than for ordinary tuners.

Treble loss, not background noise, will limit weak-signal audio quality for some listeners. The high-cut filter drops the 10-kHz response 1 dB at a signal level of 25 dBf and 3 dB at 22 dBf. Level variation due to soft muting during signal fades will be the limiting factor for others. The 1-kHz response falls 1 dB at 20 dBf and 3 dB at 18 dBf (see the curve below). An RF preamp can lower the signal levels at which these intentional effects commence.

The XDR-F1HD stereo THD figure is 13 dB lower than that of the Sangean HDT-1X.

The S/N figures are 5–6 dB worse than those of the HDT-1X and do not improve at 85 dBf. Nevertheless, with a decent signal I've never noticed any background noise, even for quiet program material. In fact, what's striking is how utterly quiet are stereo signals that have unlistenable levels of noise on other tuners (see **Sound Sample**). Evidently 68 dB of stereo S/N is enough at the volume levels I use. A second tuner measured 69 dB.

Capture ratio is how far below an unmodulated 65-dBf monophonic signal a 100%-modulated monophonic signal must be to obtain the specified quieting. With both signals in stereo, the XDR-F1HD can suppress a co-channel signal 19 dB stronger than one the HDT-1X can suppress. At my location this profoundly improves reception quality for many signals, setting the Sony apart from any other tuner I've ever used.

The astronomical selectivity figure is real. Even though both use digital IF filters, the XDR-F1HD is noticeably more selective than the HDT-1X. Sometimes the Sony can retrieve listenable signals that are buried beneath adjacent-channel splatter or completely inaudible in the Sangean. Selectivity is 30 dB greater than that of the best conventional tuner I've ever tested, one using a kHz cascade of 110-110-150-250-250 Murata ceramics.

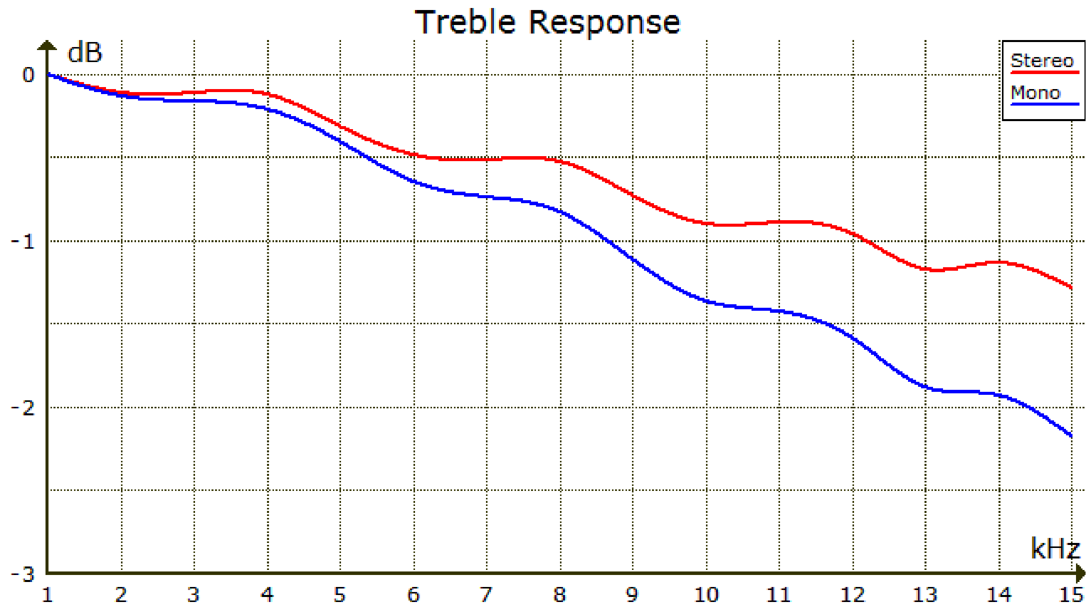
RF intermod, RF spur, and RF image are the 50-dB quieting levels for a third-order intermodulation product, an untuned signal, and a mixer image. The Sony's RF intermod figure is 5 dB better than that of the HDT-1X. RF spur is 9 dB better. Although the XDR-F1HD has just one tuned circuit in the RF signal path while the HDT-1X has two, the Sony's RF image figure is about 13 dB better due to its image-cancelling mixer. I made these RF measurements in a way that sidesteps tuner and signal generator phase noise.

RF AGC threshold is the signal level where the front-end PIN diode attenuator begins to operate. Untuned signals in the RF passband above this level may cause a weak tuned signal to become noisier. The XDR-F1HD may be more susceptible to strong-signal desensing than other tuners because its RF passband is relatively broad.

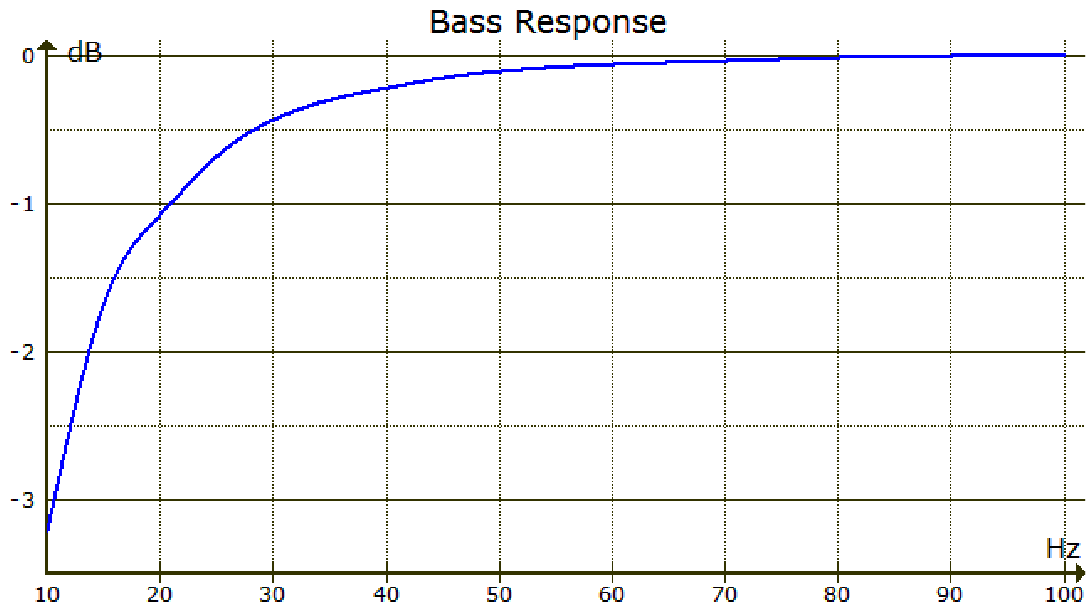
Modulation acceptance is the modulation level for 1% THD. The XDR-F1HD figure at 1 kHz may seem like overkill since FCC rules limit stations to 100% modulation (110% with SCA). But for years one local NPR station routinely deviated 140%, while another station just across the border in Mexico sometimes exceeded 250%. The XDR-F1HD had no problem with the first signal and nearly always cleanly demodulated the second. But see the graph below for low-frequency modulation acceptance, which is much lower.

Compare the XDR-F1HD latency of 27 ms to 118 ms for the HDT-1X. The Sony's audio delay is short enough to let you simultaneously play the same station in another room from a conventional tuner with negligible latency.

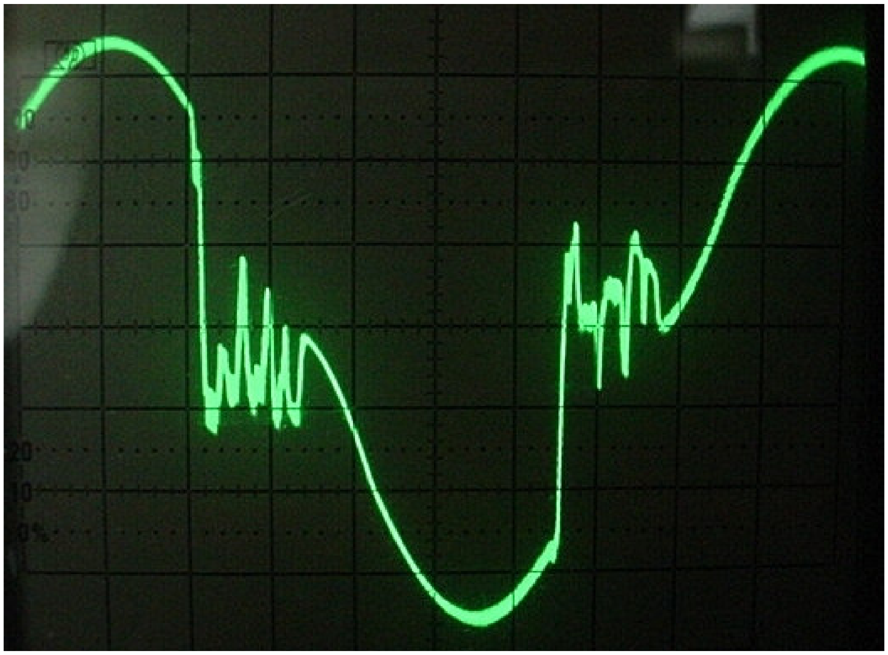
Dan Houg measured power consumption at the brightest display setting.



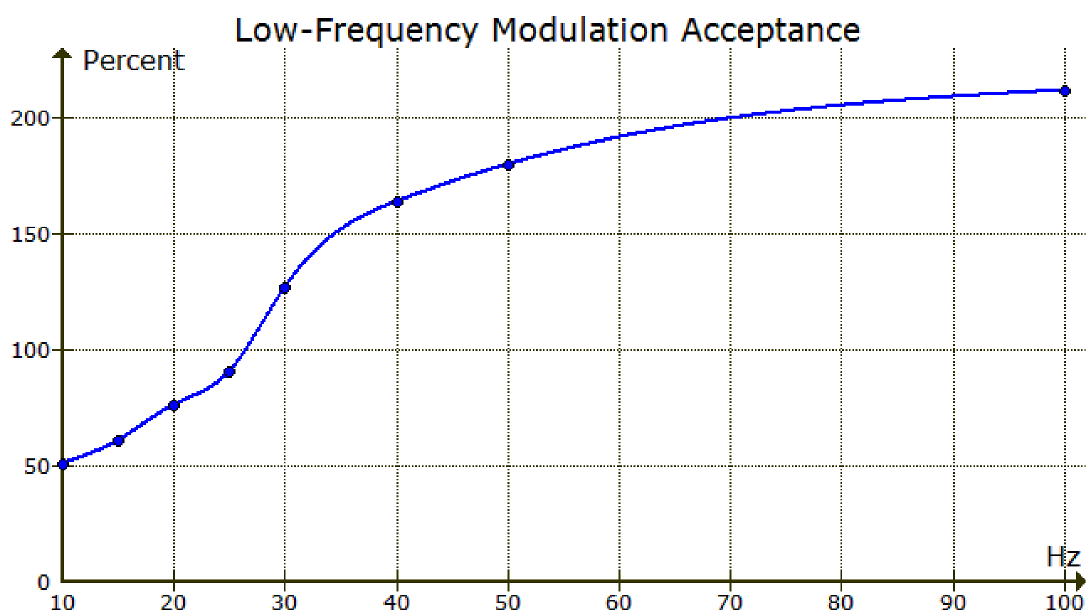
This is the left-channel treble response with an IEEE load (100kΩ || 1000 pF). I don't know why the curves differ or why they are wavy. To flatten the droop, see **Treble Correction**.



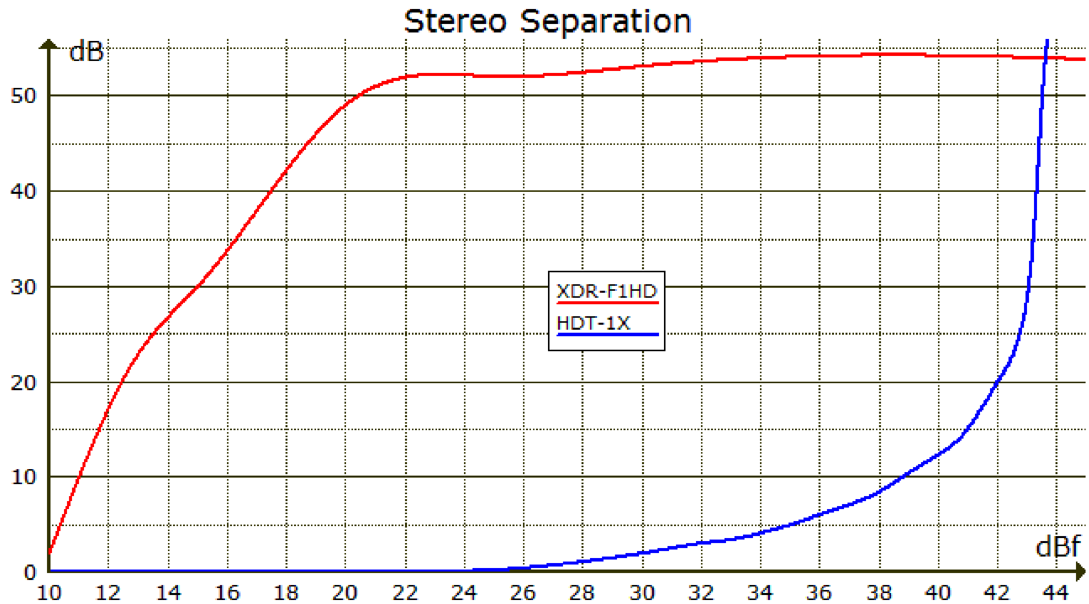
This is the bass response normalized to 100 Hz. I used 44% modulation to avoid the problem described next.



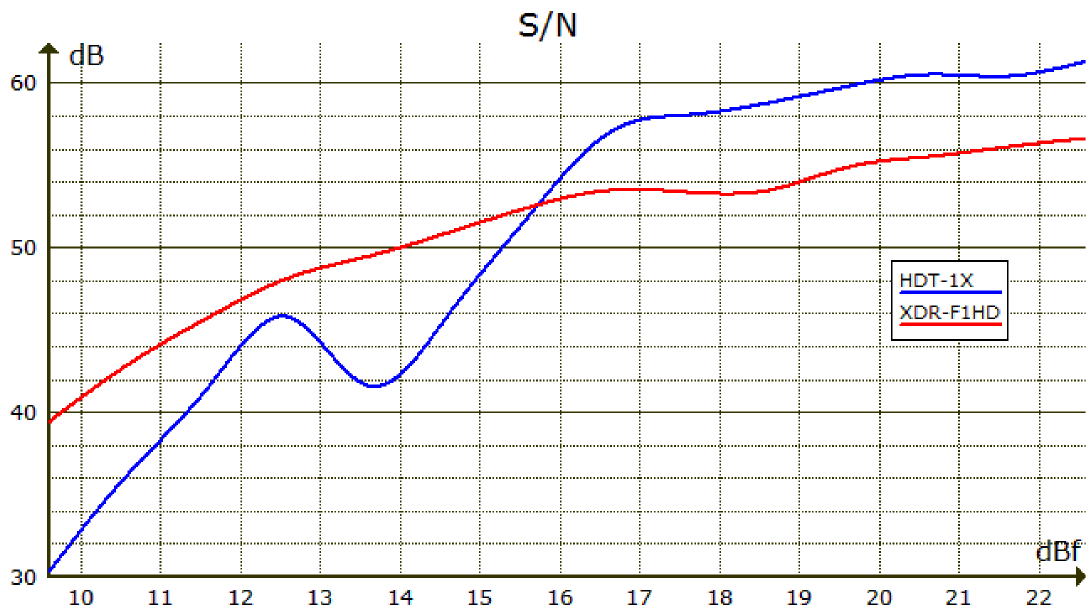
I observed these glitches for a 100%-modulated, 20-Hz, monophonic test signal. The waveform reminds me of a PLL detector losing lock, but I don't know the actual cause.



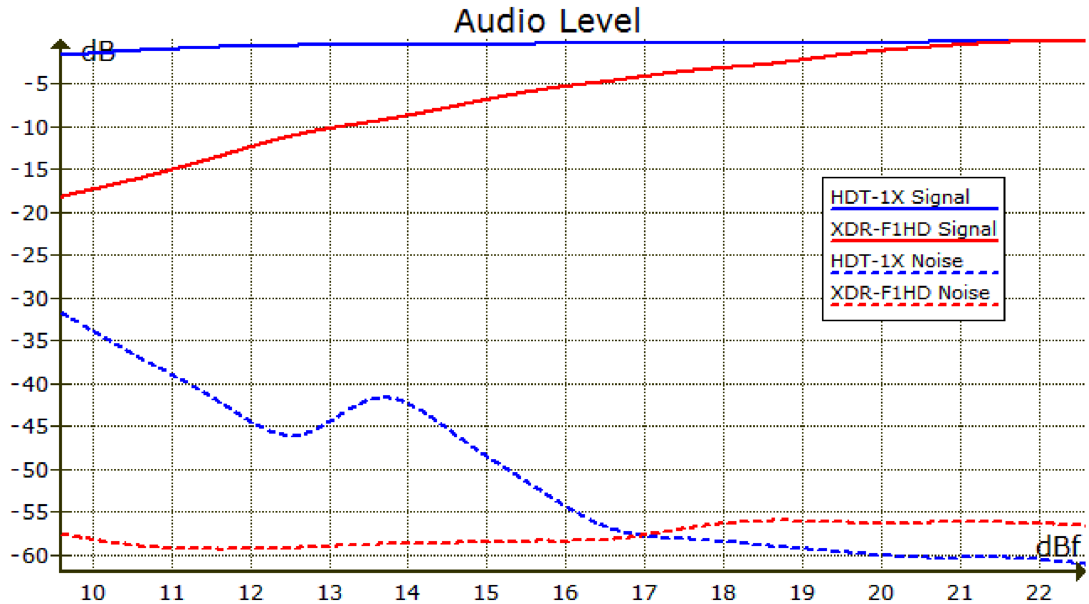
This shows the maximum glitch-free modulation level at low frequencies. I've never identified one of these glitches on a broadcast signal.



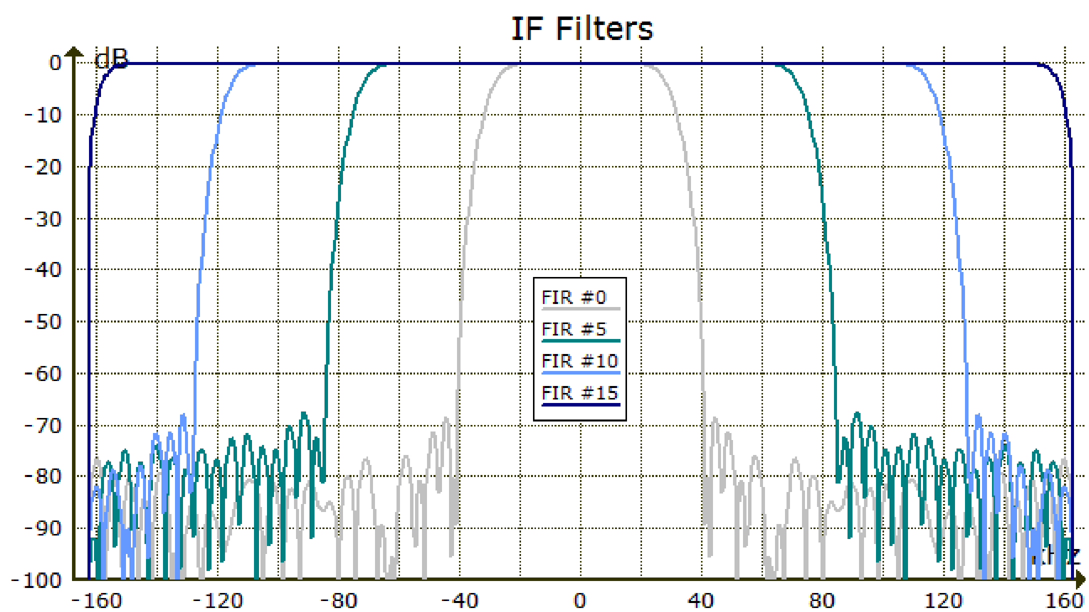
This compares 1-kHz stereo separation for the XDR-F1HD and HDT-1X as a function of signal level. The Sangean protects the listener from noise by rapidly blending the channels when S/N drops below 56 dB. The Sony's adaptive noise reduction takes care of the problem for a further 20+ dB drop in signal level without degrading channel separation.



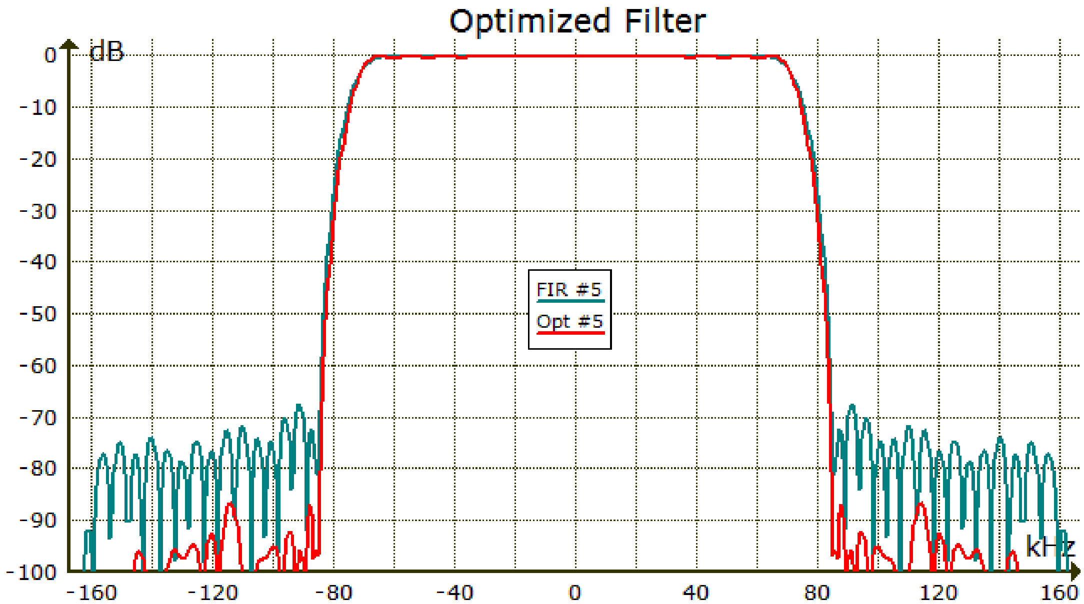
This compares monophonic quieting curves. S/N is the ratio of audio output levels for 100% 1-kHz modulation present and absent. The sudden change in slope of the HDT-1X curve just below 17 dBf marks its FM threshold. Here additive noise is large enough to begin to cause IF-signal phase reversal, which the FM detector renders as high-amplitude spikes. Spike occurrence greatly increases as the signal level drops. The XDR-F1HD S/N curve shows a gradual change in slope with no threshold. During A/B tests with the Sangean, very weak signals were markedly more readable on the Sony.



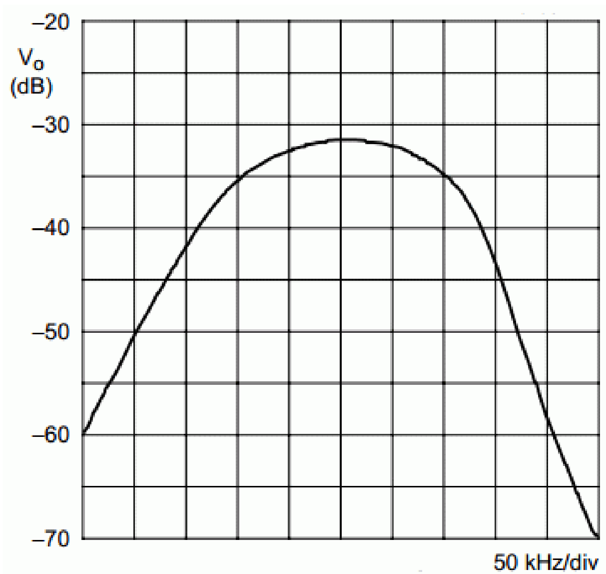
This compares audio presentation strategies at low signal levels. The HDT-1X presents a nearly constant signal level while the XDR-F1HD maintains a nearly constant noise level. The resulting XDR-F1HD soft muting is very effective at suppressing noise bursts during brief signal fades. It also seems just right for monitoring a clear channel for a band opening. Set the background noise near the threshold of audibility and a readable signal will pop up to alert you. The downside is that the loudness of a fading signal in the soft-muting region will vary. An RF preamp can mitigate this annoyance.



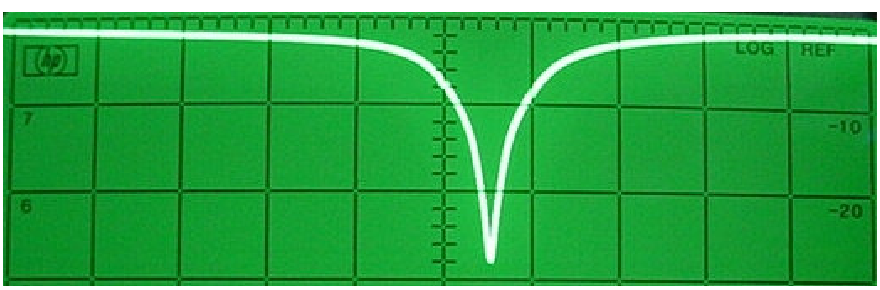
The SAF7730 provides 16 IF filter bandwidths. It automatically sets the bandwidth based on interference and modulation level. The 64-tap FIR filters use 16-bit coefficients. This graph shows the response of four of the stock filters, from narrowest to widest. The narrowest filters lower the FM threshold when the modulation level is low.



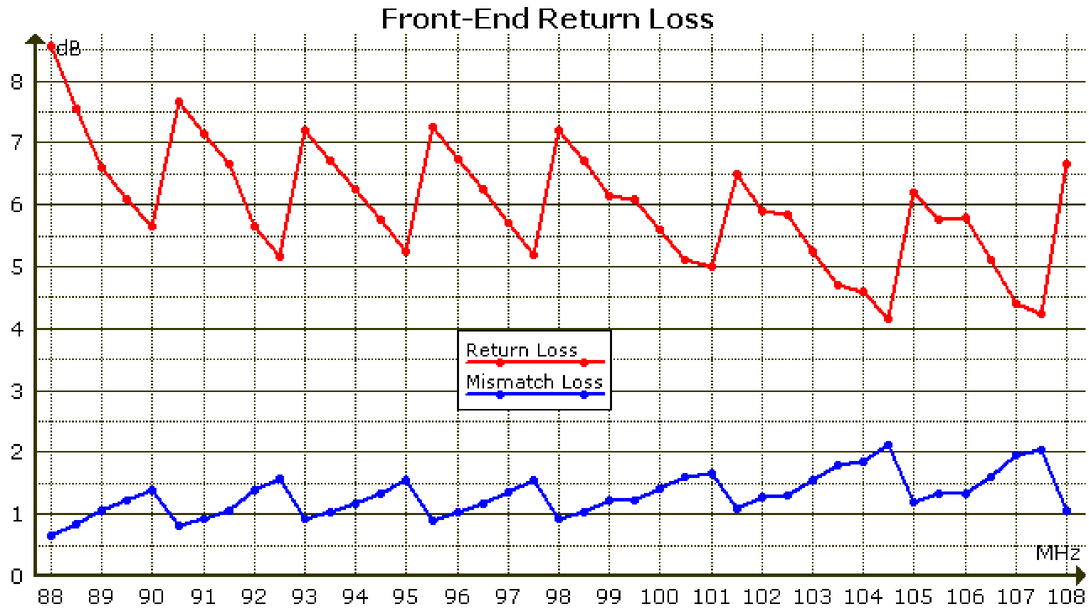
With an I²C bus controller it is possible to alter the SAF7730 filter coefficients. This plot compares FIR filter #5 with an [optimized filter](). However, reciprocal mixing of local oscillator phase noise evidently limits any stopband improvement (see the VCO spectrum below). Konrad Kosmatka could not hear a difference between these two filters when tuning broadcast signals.



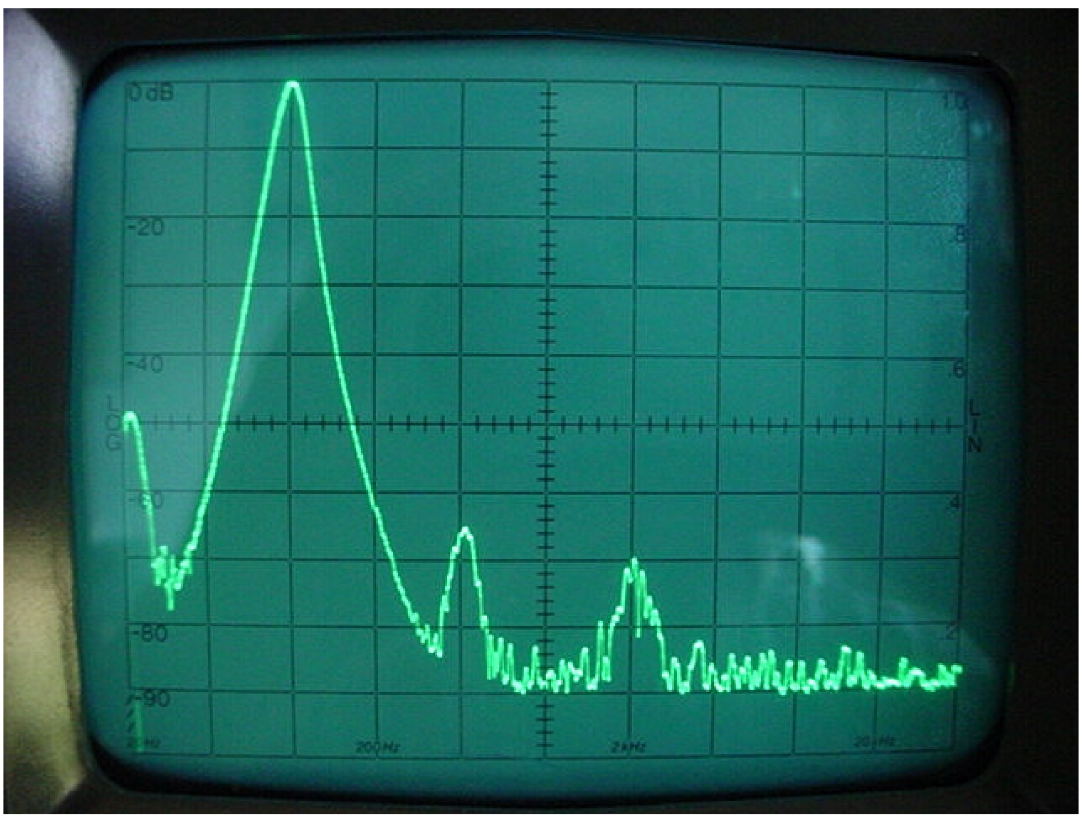
A 180-kHz Murata ceramic with this response acts as a roofing and antialias filter for the digital IF.



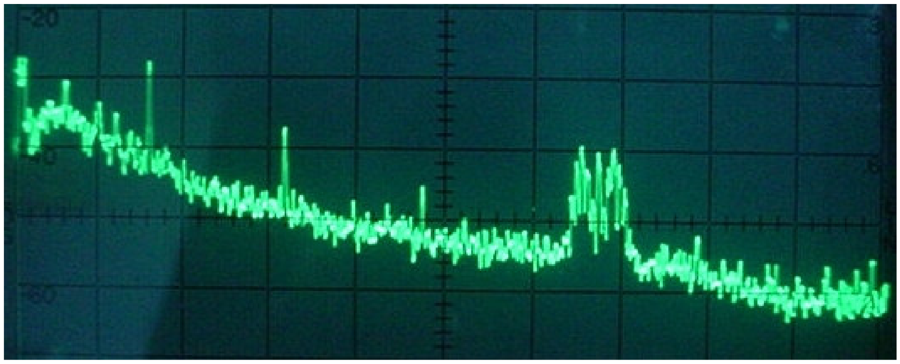
This shows RF return loss from 88 to 108 MHz with the XDR-F1HD tuned to 98 MHz. The dip is 1 MHz high. Its frequency does not monotonically increase with tuned frequency, backstepping at 90.2, 92.8, 95.4, 98.0, 101.4, 104.7, and 108.0 MHz. The backstep is as large as 800 kHz and never drops below the tuned frequency. All this suggests a misaligned piecewise-linear approximation. The backstep frequencies differ among tuner samples, which suggests that Sony automatically aligns each tuner and stores the tuning data in EEPROM.



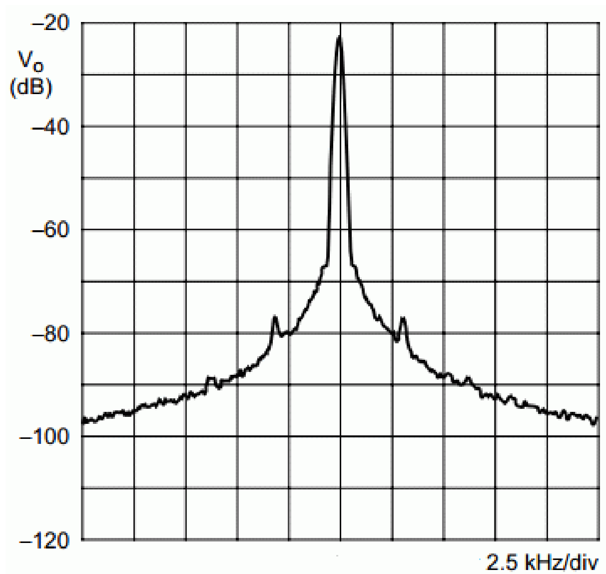
This is tuned-frequency return loss and the resulting mismatch loss. Mismatch loss directly increases tuner noise figure and degrades sensitivity. Add an RF preamp to swamp it or see **Alignment** to retune the front-end.



This is the distortion spectrum for 1-kHz, single-channel, stereo modulation deviated 75 kHz with 9% pilot.



For a strong unmodulated test signal, I could hear a faint whine in the background noise with the volume turned way up. This image shows the audio spectrum to 20 kHz using a 30-Hz analysis-filter bandwidth and postdetection smoothing. I think I was hearing the pip just above 3 kHz. Close examination reveals it to be at 3125 Hz and 78 dB below 100%, 1-kHz modulation. I have yet to hear the whine in a broadcast signal. (The thicket at −90 dB between 13 and 14 kHz was absent in a second tuner.)

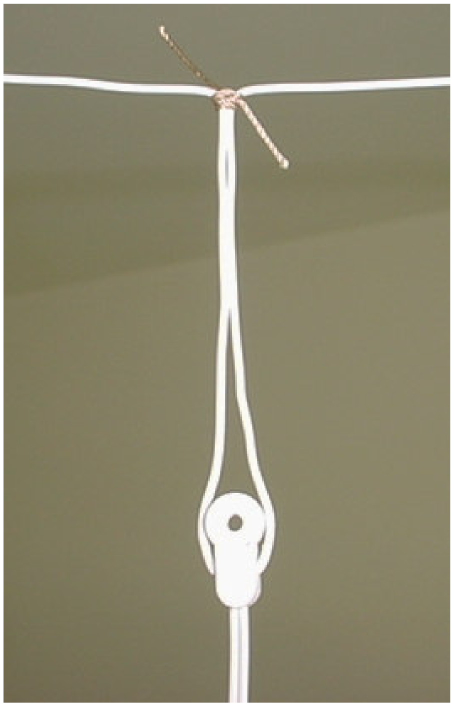


This is the spectrum of the TEF6730 voltage-controlled oscillator. The two small sideband peaks have the right offset and level to account for the whine. The vertical scale is dBc/Hz.

At 63″, the FM dipole supplied with the XDR-F1HD is rather long. Mounted in the clear about 6′ above a concrete house foundation, resonance occurred below the FM band at 85 MHz. Reducing the effective length with a piece of string as shown optimizes the response for 88–92 MHz. Tie the string so that the horizontal wires are 3″ above the mounting hole. This configuration reduced mismatch loss 0.3 dB at 88 MHz, 1.4 dB at 90 MHz, and 2.0 dB at 92 MHz. To cover 88–108 MHz, use a folded dipole instead. Tilt the antenna to maximize signal strength.

Analog AM

The AM antenna is a 4″ × 5″ rotatable loop with eight single-layer turns. Its inductance is 21.3 µH with a Q of 83 at 1000 kHz. The loop exhibits two nulls in opposite directions at all frequencies, handling it does not increase signal strength, neither AM antenna terminal is marked as ground, and each terminal has a resistance of 1Ω to ground. All this suggests that the tuner provides a balanced, differential antenna input circuit, which can reduce local noise pickup. The usual unbalanced, single-ended input causes a loop and its feedline to respond to the electric field of the electromagnetic wave as well as to the intended magnetic field. The electric field is much stronger than the magnetic for many local noise sources.

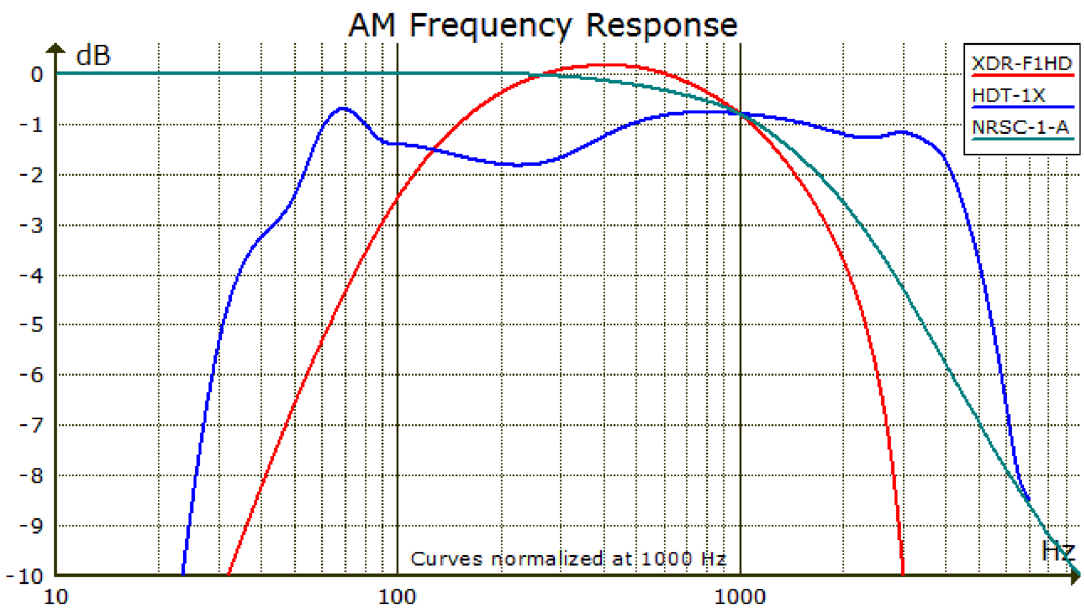


As an experiment, I turned on a noisy lamp dimmer at the far end of the house. Across the AM band the noise was much lower for the differential connection than when I reconnected one feed wire to tuner ground. The schematic shows a single-ended input circuit, but a red jumper wire on the motherboard and another inside the tuner module provide the differential input.

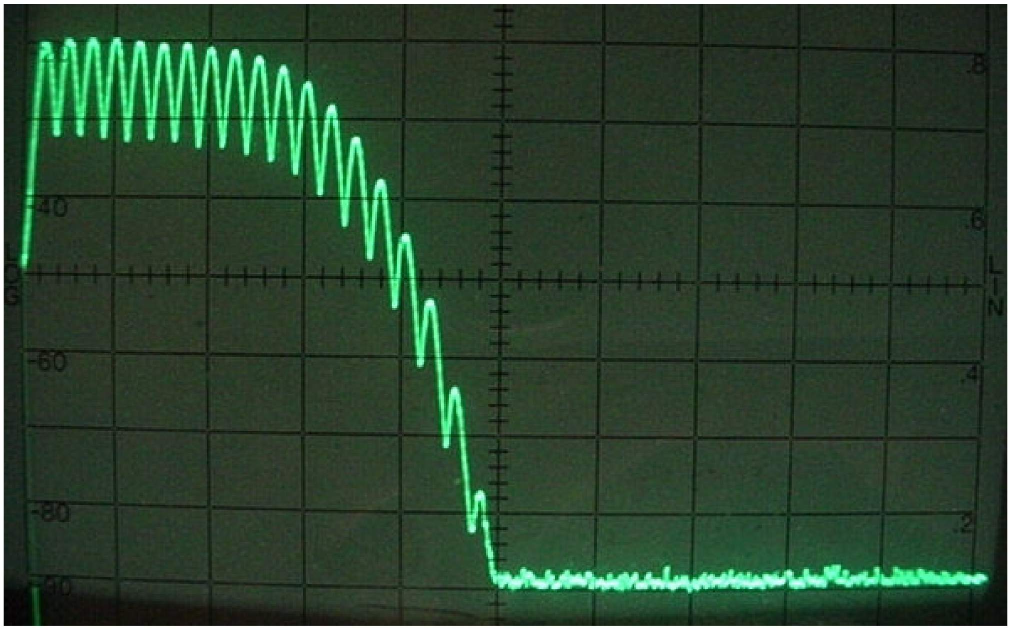
For two loops I examined, the insulation on the wire ends was cut but not stripped. I wonder if this explains the occasional report of no AM reception. The stripped wire seemed rather fragile when inserted into the spring-loaded antenna terminals, which bent and separated the tiny strands. I tinned them to add strength.

The operating instructions warn not to place the loop near the tuner as it may pick up noise. I noticed some low-level interference at the low end of the band, but it was easy to minimize by repositioning and reorienting the loop.

I connected a signal generator terminated in 50Ω between one antenna terminal and the shell of an RCA audio jack. Sensitivity was the same for both terminals, confirming the input balance. At 1500 kHz, −93 dBm yielded 30 dB S/N for a 90%-modulated, 1-kHz tone. 400-Hz THD at 30% modulation was 0.08%. It reached 0.14% only at −10 dBm, and the audio stayed clean to 0 dBm. This is a much higher RF level than the Sangean HDT-1X tolerated without noticeable audio distortion. Both the Sony and Sangean use an RF amplifier stage.



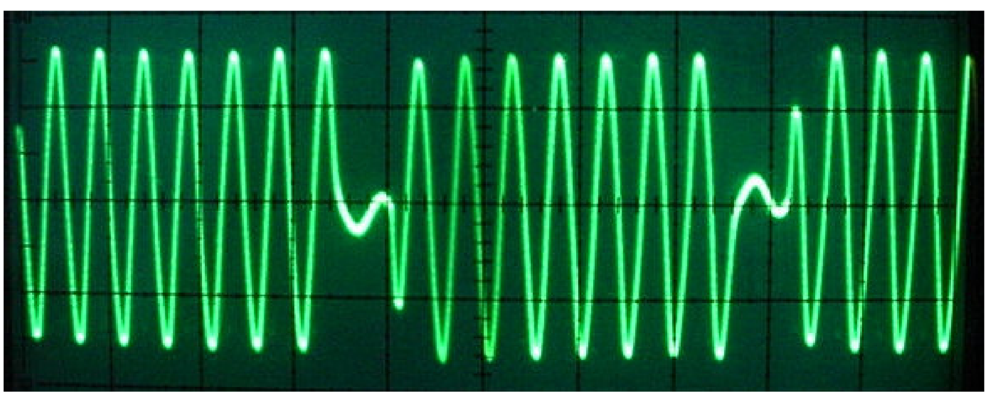
This compares the frequency response of the XDR-F1HD and HDT-1X with the NRSC-1-B AM deemphasis standard. The error is easily audible for both tuners. I wondered whether the Sony's bass roll-off might be intended to comply with the old tonal balance rule for AM radios, which states that the product of the low- and high-frequency limits in cps should be about 500,000. The bass response actually extends more than twice as far as the rule stipulates.



This is the audio output spectrum for a test signal consisting of NRSC-preemphasized tones spaced 250 Hz. The horizontal scale is 1 kHz/div and vertical is 10 dB/div. The plot confirms my listening impression that the XDR-F1HD severely rolls off the AM high-end. The response is down 24 dB at 4 kHz.

I tried flattening the treble response with an octave equalizer, but I wasn't able to make a worthwhile improvement. Although the unequalized bandwidth is less than that of a good telephone circuit and the treble roll-off attenuates sibilants and certain vowel formants, I had no trouble understanding speech.

The benefit of the bandwidth limiting, which is done at IF, is immunity to adjacent-channel interference. It is easy to receive a weak skywave signal next to a strong local. Only the occasional sibilant splat from a wideband adjacent may intrude. Unlike the HDT-1X, the XDR-F1HD has neither variable IF bandwidth nor synchronous detection. Illustrating the latter was distortion on some skywave signals during selective fades.



The XDR-F1HD has an automatic noise blanker. This shows it blanking lamp dimmer pulses in sinewave modulation (2 ms/div). Blanked audio sounded somewhat rough, with 1.2-ms waveform segments erased every 8.3 ms. Still, with strong pulse interference the audio sounds much better blanked than not.

AM latency is 3 ms. Compare to 125 ms for the HDT-1X.

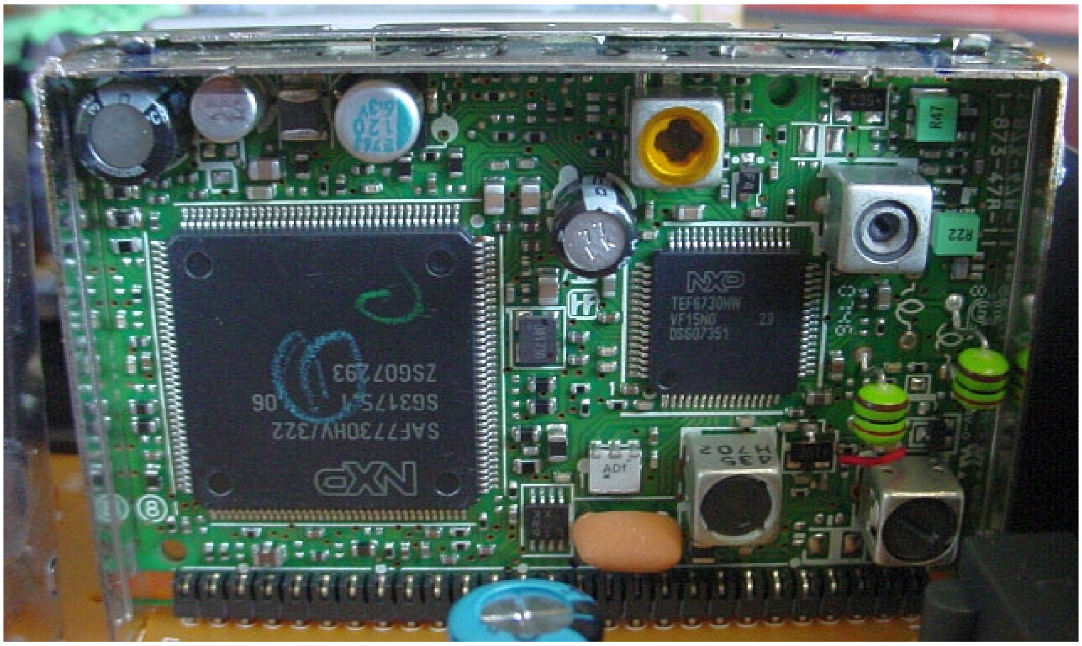
HD Radio

Except for one occasion when the XDR-F1HD locked to an FM signal and the HDT-1X did not, the tuners performed the same on HD Radio on both AM and FM. I noticed just two operational differences. First, the Sony will flash its HD indicator when tuned 300 kHz above or below an FM HD signal. Second, when manually tuning a weak station running service mode MP3, occasionally only HD-3 appears. Once locked, the analog signal and the other digital channels become tunable. This is the only firmware bug I've found in the XDR-F1HD.

A realigned XDR-F1HD reliably locked to a 29-dBf FM HD Radio signal with −20-dBc digital sidebands, as did a realigned HDT-1X.

For an FM station transmitting silence on HD, I measured the unweighted residual noise as 84 dB below the level of a 1-kHz sine wave with 1.5V peak amplitude, a typical HD Radio waveform amplitude. I used a 200–15,000 Hz bandpass filter per IEEE 185-1975. For the same reference level, an HDT-1X yielded 85 dB S/N during HD mute.

Alignment

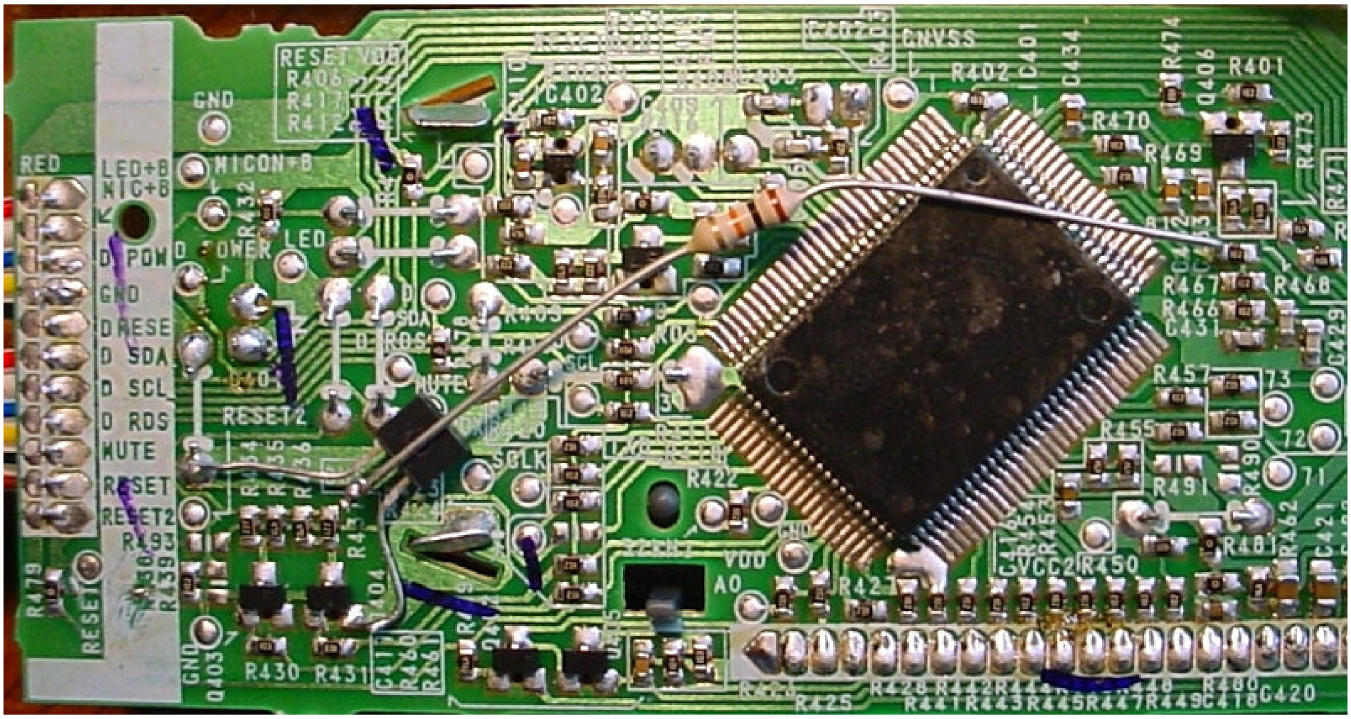


Following Peter Körner, I unsoldered the right-hand shield from the tuner module. The FM antenna coil is near the upper-right corner. Just as Peter found for two tuners, rotating the slug a quarter turn counterclockwise increased the audio level 2 dB for a modulated signal in the soft-muting region. I peaked the coil at 96.8 MHz, near the center of a varactor tuning segment, and replaced the shield. After the module warmed up but without the cabinet in place, 50-dB quieting sensitivity at 96.8 MHz had improved 1.4 dB to a remarkable 12.6 dBf. It also was 12.6 dBf at 95.3 and 95.4 MHz, endpoints of adjacent tuning segments. Equal sensitivity at adjacent endpoints should be optimal. (Immediately after replacing the shield, I measured 12.0, 12.2, and 12.8 dBf. I was just lucky that the sensitivities equalized after the module warmed up. A shield adjustment hole would let you align the tracking at a higher temperature, one closer to that with the cabinet in place.)

Near the lower center is the IF coil. In one tuner Peter was able to increase the weak-signal audio level 1 dB by peaking it. The coil was already peaked in his second tuner and in mine. This adjustment does not affect stereo distortion.

In the lower-right corner is the AM input transformer. It is not varactor tuned and I did not adjust it. The red jumper wire next to the transformer, along with another on the motherboard, are factory changes that provide differential RF input.

Disabling the Backlight



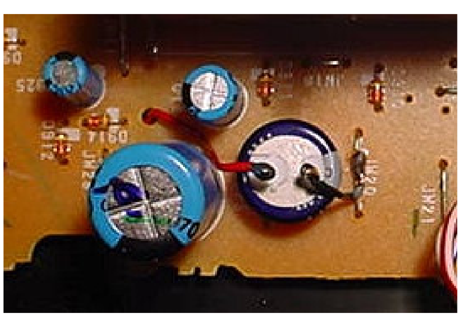
Even when dimmed, the LCD may be too bright in a bedroom at night. Cutting a trace on the controller board and installing a transistor and resistor will disable the backlight in standby.

The transistor switches the backlight ground return. The controller power-on signal drives the base through the resistor. Total backlight current is 40 mA at the brightest setting. I used a Zetex ZTX1051A and a 10kΩ resistor. Any NPN transistor will work given enough base drive. The power-on signal minus V_{BE} is about 2.4V. If you use a transistor with a saturated current gain of 50, for example, use a base drive of 40/50 = 0.8 mA and a resistance of 2.4/0.0008 = 3kΩ. This value should work for a 2N2222A. Limit the drive current to 4.5 mA in all cases. A 2N7000 FET requires no resistor, but the gate drive is marginal at maximum backlight current.

Remove three screws from the pushbutton board and two from the controller board. Pull the boards and lay them to the right of the tuner. Cut the horizontal ground trace under the T in RESET just to the right of R479 in the lower -left corner of the board. Solder the transistor emitter to the ground jumper pad to the right of MUTE. Solder the collector to the lower right lead of Q404. Solder the resistor between the base and the left lead of R468. The body of the resistor must clear the controller chip.

R438, located just above GND in the lower-left corner of the board, determines the LOW brightness level. Increase the 1kΩ value to dim it, or remove the resistor to disable the backlight in LOW.

Extending Memory Retention

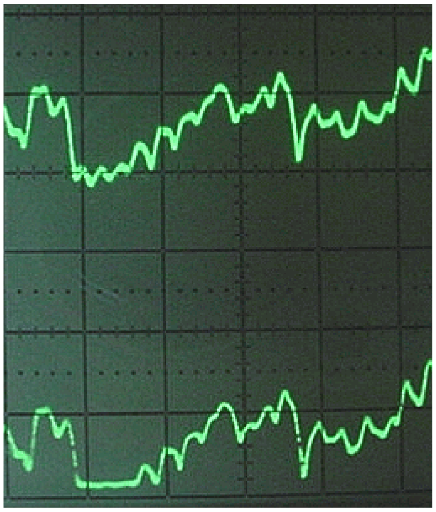


Although the XDR-F1HD has two EEPROMs for nonvolatile storage, neither retains the tuned frequency or station presets. This information remains valid in controller RAM only for a few minutes after power is lost. This is long enough to ride through a brief power interruption, but too short to let you switch off the tuner overnight with another audio component. (You'd still have to press the power button to turn it back on since the tuner always powers up in standby. But see **Power Up**.)

C926, a 4700-µF motherboard electrolytic, provides V_{CC} backup for the controller. Paralleling a common 0.047-F memory backup capacitor extended my tuner's backup time to one hour. This lets it accommodate longer power outages. A 1.5-F supercapacitor should extend the time to at least one day. Any capacitor should be rated for 3.6V minimum. If its equivalent series resistance is less than 50Ω, add a series 47Ω ¼W resistor to limit the surge current. C926 should be paralleled, not replaced. Proper controller shutdown requires a fairly stiff supply voltage. To add the capacitor without removing the motherboard, connect its positive terminal directly to the cathode lead of D914 instead of using the adjacent hole to reach the solder side. Connect the negative terminal to jumper wire JW20 as shown.

Hillel Hachlili's battery backup offers much longer retention time.

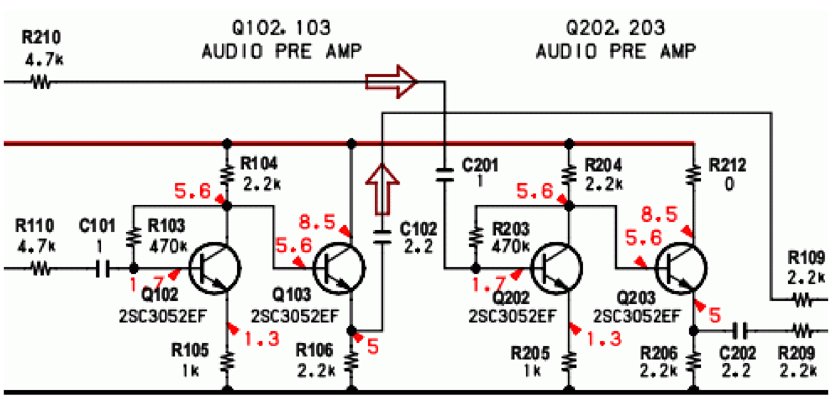
Extending Audio Headroom



The audio amplifiers in my XDR-F1HD clipped on digital signals with abnormally high audio levels. This image shows one such clip. The lower waveform is output at the RCA jack. The upper waveform is audio from the tuner module, inverted and scaled to match the lower trace. The baselines are at the top of the image and two divisions from the bottom; the waveform segments are entirely negative. The horizontal scale is 5 ms/div and vertical is 1V/div. One division from the left the lower waveform clips at −1.8V for several ms. The upper waveform goes to −2.2V.

Analog signals never clip, and neither do the great majority of digital signals. Measured over several seconds, the RMS level of the digital signal shown was 3.7 dB higher than that of the station's analog signal. The peak digital amplitude was 2.5 times as great as the peak analog amplitude. This digital signal was *hot*.

In my tuner the 8.5V that powers the audio amplifiers was somewhat low at 8.27V. To provide a bit more headroom, I added 30kΩ across R904 to raise the voltage at tuner module pin 5 to 8.5V. A single resistor from collector to base biases the audio gain stages. This simple method is beta-dependent. The high beta of the transistors installed in my tuner yielded 4.5V at the collectors, well below the nominal 5.6V and too low to prevent clipping on extreme negative peaks. I added 12kΩ across collector loads R104 and R204 to raise the voltage to 4.9V and to reduce the signal amplitude. Both increase headroom. The output level dropped 1.5 dB to 0.6V. Your tuner may require different resistor values or it may need no 8.5V or bias correction at all.



In addition to clipping, the bipolar amplifiers in my tuner degraded second-harmonic distortion 10 dB. To replace them, see **Treble Correction**.

Clipping is so shallow and infrequent in my tuner that I believe it is inaudible. But I wanted to be able to make accurate peak/RMS measurements. And while the distortion degradation is rather alarming, I can't perceive any distortion on an isolated sinewave, which is a very sensitive test.

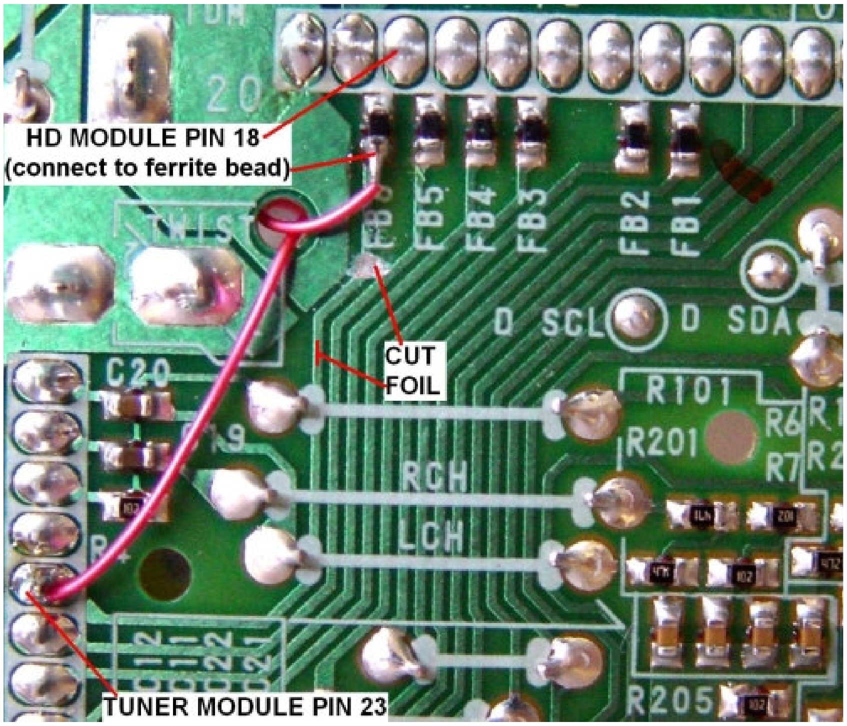
The SAF7730 has no output-data pins so modification to provide digital output isn't possible. D/A conversion uses 24-bit data, 128X oversampling, third-order noise shaping, and four-bit switched-resistor networks with data-weighted averaging.

Forcing Monophonic Reception

You may want to force monophonic reception when receiving very weak signals. Mono eliminates any L−R noise that may slip past the adaptive noise reduction. If your amplifier has no mono function, you can wire an outboard SPST switch across the XDR-F1HD output terminals. Emitter followers through 2.2kΩ resistors drive the outputs. Interconnecting them will not stress any component. A simple alternative for mono DXing is to parallel the outputs with a Y-cable. Always force monophonic reception when making a single-channel recording.

When driving my tuner with a monophonic signal, the unloaded output amplitudes differ by 0.6%. Allowing for the 5% tolerance of the 2.2kΩ output resistors, interconnecting the outputs should suppress L−R at least 25 dB.

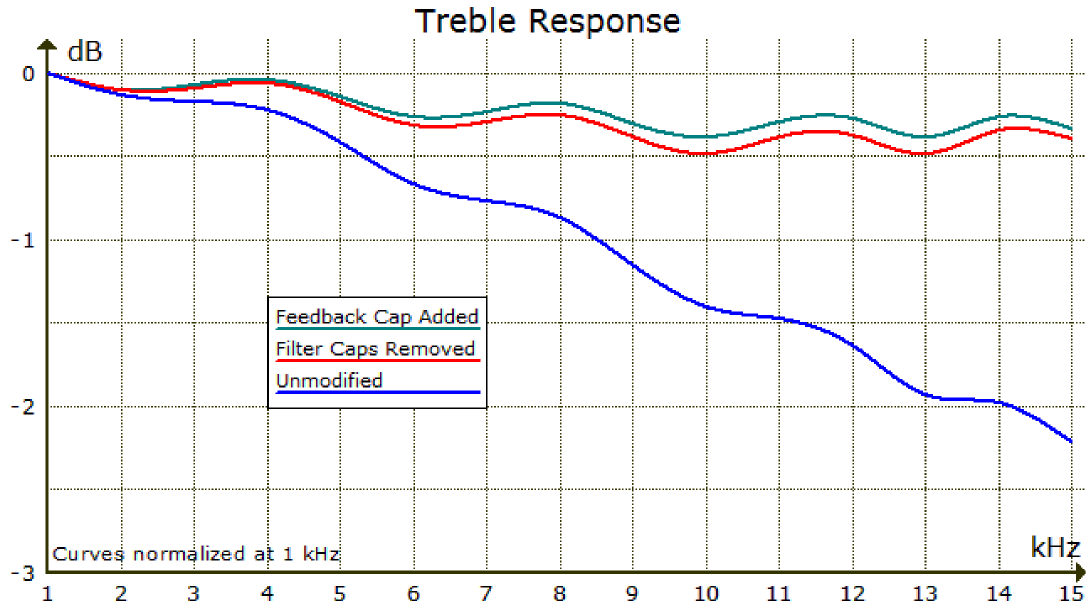
Forcing Analog Reception



Occasionally you may wish you could force analog reception. You may not care for the transmit processing a station uses for its digital signal, the HD-1 bit rate for a multicast signal may be low enough to cause coding artifacts, the tuner may switch back and forth between analog and digital on a marginal signal, or a distant co-channel HD Radio signal may co-opt the analog signal you're trying to receive. And then there is AM HD, which always sounds funny to me. This modification will let you keep the tuner in analog mode.

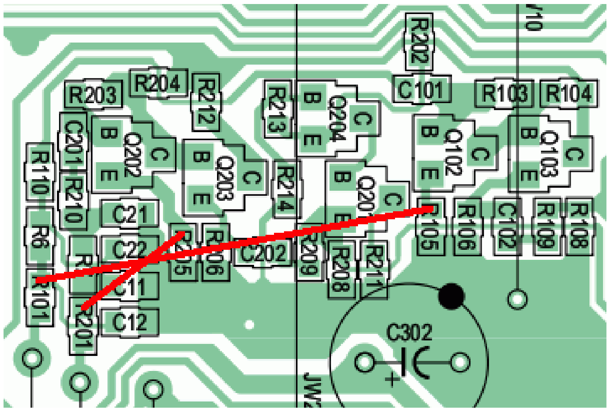
This photo from Bob Meister, WA1MIK, shows where to cut a trace and add wires on the motherboard. Run the wires to an SPST switch mounted anywhere convenient. The switch interrupts a control signal that originates at pin 18 of the HD module and passes through ferrite bead FB6 to pin 23 of the tuner module. When high, the signal tells the tuner module to use the HD Radio bitstream. The display will indicate HD reception for both switch positions, but you'll be listening to analog audio with the switch open. If you mount it on the rear panel, you can use extra contacts to indicate the switch state with a bright red LED. Mount it on the controller board at the edge of the LCD to alter the display color in forced-analog mode.

Treble Correction

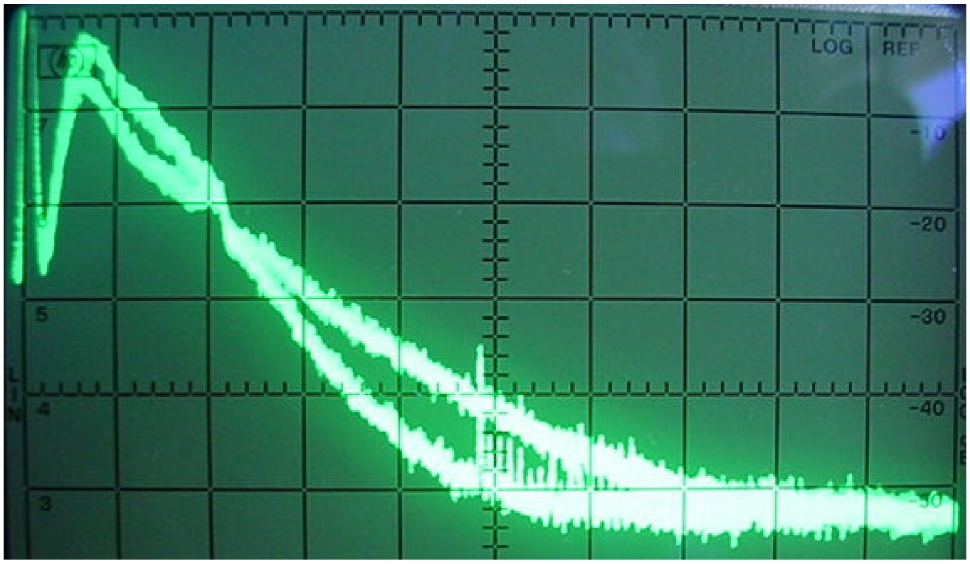


Each D/A feeds a ferrite bead and shunt capacitor within the tuner module. The module drives two-section, passive, RC lowpass filters on the motherboard. The filters suppress low-level ultrasonic noise that extends to a few MHz, but they also cause the frequency response to droop within the audio passband, as shown by the blue curve. The ultrasonic noise is due to D/A noise shaping that maximizes S/N within the audio passband.

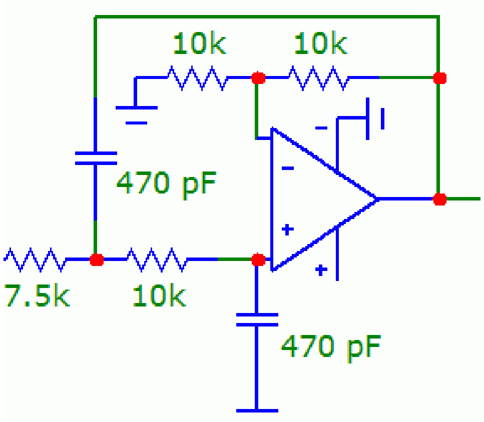
I found three ways to correct the RC filter droop. The first is to remove the filter capacitors. The red curve shows the resulting treble response. The capacitors, C11, C12, C21, and C22, are in the lower-right corner of the preceding photo and in the image below.

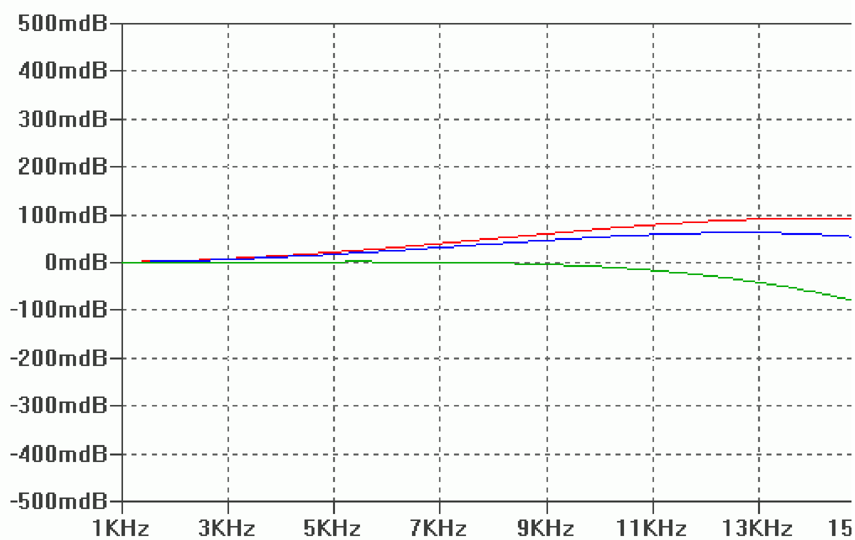


The second way to correct the droop is to add a feedback capacitor from the audio stage to the filter. The green curve shows the response. You may find this method easier than unsoldering surface-mount parts. With the PCB oriented as above, connect 0.01 µF between the upper ends of R101 and R105. Add another between R201 and R205 for the other channel. The capacitors must be very thin for the PCB to properly seat.

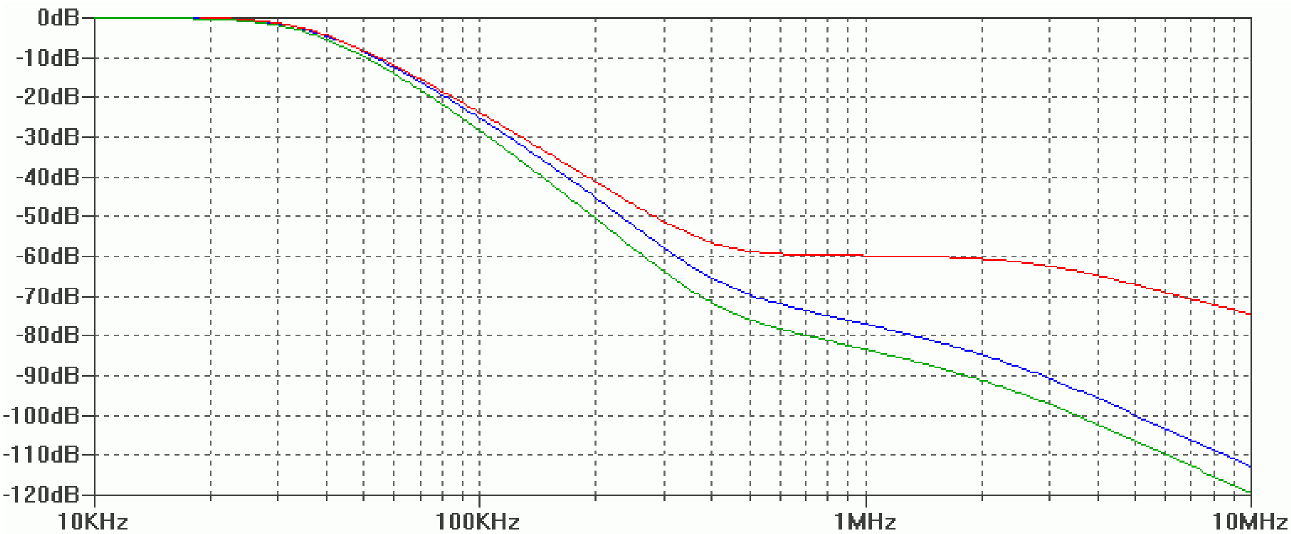


This is the output noise spectrum for both methods with an IEEE load. A 1-kHz tone 30 dB below 100% modulation exercised the D/A. The frequency span is 0 to 5 MHz, the vertical scale is 10 dB/div, and the resolution bandwidth is 10 kHz. Below 1.1 MHz the noise is greater for the feedback capacitor, and above it is lower. With no modulation the wideband noise level was −50.2 dB for the feedback capacitor and −53.8 dB with the filter capacitors removed. The residual ultrasonic noise for either method should cause no problem unless RF leakage from the audio signal path interferes with AM reception.





For both methods described above, the ultrasonic noise is visible on a scope. This offends the eye if not the ear. To eliminate it altogether, install active lowpass filters. Chebyshev-inspired response ripple compensates for the residual 0.5-dB roll-off. The red curve is with no tuner load, blue is 47kΩ || 470 pF, and green is 100kΩ || 1000 pF (IEEE). The circuit model includes the load and the components that cause the roll-off, but the schematic is for the filter alone. Use part values within 2% of the those shown. Use a wideband, dual op-amp with rail-to-rail input/output rated for V_{CC} = 8.5V, such as a TLV2372.



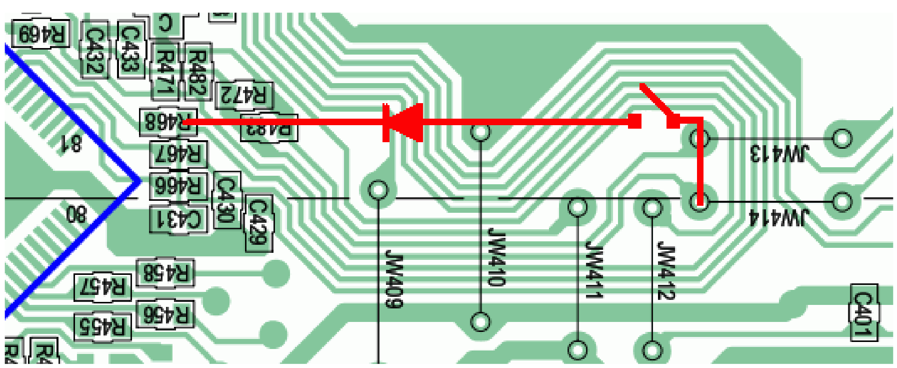
This is the wideband response using a TLV2372.

The active filters have 6 dB gain so that they can replace the bipolar audio amplifiers as well as the RC filters. This eliminates clipping on digital signals with abnormally high levels and reduces harmonic distortion for all signals, though I believe both impairments are inaudible in a stock tuner.

To install the filters, connect tuner module pin 4 to filter ground. Connect the positive terminal of C302 to the op-amp power pin. Solder a 0.1-µF ceramic between the power and ground pins. Cut jumper wires JW14 and JW15 and connect tuner module pins 26 and 27 to the filter inputs. With the HD module at the top, input to C102 is on the right and input to C202 is on top. Isolate each input by cutting the trace to it, or by remounting the capacitor vertically on its output pad, or by removing R106, R206, Q103, and Q203. Connect the op-amp outputs to the capacitor inputs, with the filter connected to pin 26 driving C102.

Treble correction also benefits HD Radio audio. AM HD response extends to 15 kHz. FM HD may go to 20 kHz, where the RC filters are down an additional dB.

Power Up

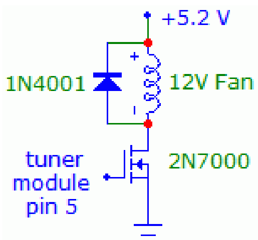


Unattended applications may require the tuner to power up in operating mode. Adding a silicon diode to the controller board between jumper wire JW414 and either end of R468 will accomplish this. However, if you press the power or reset buttons, the tuner will power down and remain off until the controller V_{CC} disappears. A simple solution is to wire an SPST toggle switch in series with the diode. The tuner will operate normally when the switch is open. When closed it will power up in operating mode. If you accidentally hit the power button or must reset the tuner, open the switch.

Temperature

With a thermistor attached to C908 on the power board and the top cover in place, I measured 63° C (145° F) after one hour at 25° C ambient in still air. I converted the +10.5V supply from half- to full-wave rectification, intending to reduce transformer losses and lower the ripple current in C908. After conversion the temperature rose more slowly, but it was only 0.6° C cooler after an hour.

Ken Wetzel added extra feet to enlarge the space under his tuner and improve air flow. This has only a minor effect on internal temperature, but it's easy to do.



A tiny fan mounted inside the tuner should greatly lower its temperature. Many 12V fans become inaudible when operated at a lower voltage. Try the unregulated +5.2V, switching the fan and a back-biased diode with a transistor driven by the 8.5V.

Reducing temperature will prolong electrolytic capacitor operating life. The expected lifetime doubles for each drop of 10° C. A fan might well lower the temperature 20° C, quadrupling capacitor life. The tuner module contains four small electrolytics that would be difficult to troubleshoot and replace. To estimate their operating life, I used the equations on page 14 here. The capacitors with the least voltage derating and shortest expected life are Nichicon type SA and ZS. At 18° C ambient, I measured 57° C at the outer module surface near the capacitors. Using 59° C for 20° C ambient, the expected life is 4.4 years of continuous operation.

The three filter capacitors in the HD Radio module are tantalums. Unlike aluminum electrolytics, tantalums do not gradually wear out. The reliability nomograph on page 80 here suggests that the failure rate for the three capacitors should be extremely low. A tantalum usually fails by shorting. This will disable the tuner, but it makes the part easier to locate than an open or high-ESR electrolytic.

Although it runs somewhat hot, the design seems safe. The transformer primary has an internal fusible link and each secondary winding drives an external fuse. If a hot transformer or filter capacitor shorts, a fuse should blow. Each of the voltage regulators has thermal overload and short-circuit protection. If a regulator overheats or its load shorts, it will shut down.

More Modifications

Marty Duling augments the cabinet venting here. Hillel Hachlili adds external cooling and battery backup here. Julian Hardstone describes experiments and modifications here. Konrad Kosmatka describes a versatile I²C bus controller here.

Other Devices

Although I haven't verified their performance, the XDR-S3HD table radio, XDR-S10HDiP docking table radio, and XT-100HD car adapter use the same DSP modules and algorithms as the XDR-F1HD.

Other Reviews

The Audio Critic reviews the XDR-F1HD here. CNET reviews it here. Ira Wilner gives a broadcast engineer's perspective here, as does Dan Houg here. DXers David Pierce and Mike Bugaj offer reviews here and here.

Sound Sample

This sound sample compares the Sangean HDT-1X and the XDR-F1HD on a 67-dBf FM stereo signal made noisy by an adjacent-channel HD Radio signal.