RF to Video Converter for Timex/Sinclair Computers

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I recently rediscovered my cache of Timex/Sinclair TS-1000 computers. I had always figured they would be handy for controller purposes. Yes, PIC chips are powerful and low cost, but the Timex/Sinclair devices were in hand, I did not need a separate computer and software package to program them, and using retro computer technology from the early 1980s would be cool. Like many early microprocessor based computers, the Timex/Sinclair devices were designed to use a regular color or B&W television set for the monitor. However, modern television receivers do not have AFC or the mechanical fine tuning capability required to handle free-running (non-crystal controlled) video modulators. This is similar to the problems experienced when using a FM microphone in conjunction with a digitally synthesized FM tuner. I could have dissected the TS-1000 and intercepted the video just ahead of the modulator, as has been done by others, but I wanted to modify the computers as little as possible. The modulation format is either European or American and the RF output is on lower VHF channels (2 or 3) or a mid UHF channel (33) depending on the model and the market country. The computer has the wiring for either modulation format. The selection is made by changing on-board jumpers. Being in the US, I was interested in the American format and lower VHF channels. So, for computer devices such as my Timex/Sinclair TS-1000 computers, I needed an instrument that is essentially a broadband RF amplifier followed by a video detector and a video amplifier/driver. The inclusion of a gain/level control and video signal level meter would also be nice but not essential.

The instrument needs to accept RF signals operating anywhere from television channel 2 through channel 33 (60 – 590 MHz) or higher. My first thought was to cascade several MAR MMIC amplifiers, a diode detector, and one or two stages of video amplification. But before committing to a final design, some bench testing was in order.

I tried some simple experiments with one of my TS-1000 computers. First, I naively tried directly detecting the RF output signal. A coaxial RF detector with a 1N23 diode showed no visible output on my oscilloscope even when using 1mV/cm display vertical sensitivity. I added a 20dB RF amplifier between the TS-1000 and the detector and could then see a video signal with a peak of just over 10 millivolts. With 20 dB representing a voltage gain of 10, I would have expected to have seen a signal 1 division high without the RF amplifier, but at the low signal levels, the detector is non-linear and inefficient. Fortunately, with a two-level image format, amplitude distortion is not a critical issue. Obviously, more RF and/or video gain was needed.

Adding more RF amplifiers helped. I added two amplifiers to get a total of 56 dB gain and 0.5V peak video output which was barely sufficient to drive the video monitor. I imagined at least 60 dB gain was needed. Of course, some of the gain could be at the video baseband frequencies and not all at the RF frequencies. I initially wanted a net video gain of 3-10 dB with an output impedance of 75 Ohms. Incidentally, I tried several Timex/Sinclair TS-1000 computers and all had significantly greater output on channel 3 versus channel 2.

Under FCC Part 15, subpart H, rules, the peak RF output signal from a modulator must be less than 6mVrms into 300 Ohms or 3mv into 75 Ohms. Even a poor television should produce a noise free picture with a signal level of 1mVrms. Ignoring detector losses, this would imply that I would need a maximum gain of 71 dB and a minimum of 61 dB gain for my video detector system. This value seemed reasonable based on the workbench tests.

The selection criteria for the RF amplifiers included bandwidth, gain, maximum output power without signal compression, and availability from my junk box. Operation from +15V was a bonus.

I researched the documentation concerning a Mini-Circuits ZFL-2000 wideband amplifier I own. The amplifier covers from 10 to 2000 MHz, has a gain of 20dB, and the 1 dB compression output level +15dBm (1.2Vrms). The bandwidth of the amplifier is a bit excessive, but still usable. The amplifier does run off +15V. I also have several ANZAC model AMC-183 RF amplifiers covering 10-1000 MHz. The amplifiers have a nominal gain of 28.5 dB and the 1 dB compression output level is +13 dBm. The ANZAC amplifiers also run off +15V. Using two of the ANZAC RF amplifiers connected in series, I was able to get good direct detected video signals. However, the system would occasionally oscillate. Sequencing the power switch would kill the oscillation, but I wanted a more stable design. I decided to reduce the net RF gain to improve system stability. I have seen many projects that looked good on paper fail when too much gain was stuffed into close quarters. Splitting the gain between RF and video frequencies improves the system stability. Using one AMC-183 10-1000 MHz RF amplifier and one ZFL-2000 amplifier meant 8.5 dB less gain which would have to be made up with the video amplifiers and the amplifier chain was stable. The two RF amplifiers are mounted on an aluminum bracket which acts as a mechanical brace and a small heat sink. Together, the amplifiers dissipate fewer than 2 Watts, so not much heat sinking is required. A TEXSCAN model RA-70 0-10 dB stepped attenuator connected between the second RF amplifier and the detector is used as a level control.

The output line from the stepped attenuator is terminated with a capacitively coupled 47 Ohm resistor. The detector is a 1N60 germanium diode. The 1N60 proved to have less distortion than the 1N23 or a 1N5711. The detector load, 2.4K, is a compromise between signal amplitude and video bandwidth. The detector is followed by a unity gain buffer and five stages of LF356 opamp video amplifiers. The gain for each video amplifier stage was purposely limited to 2X or lower to maintain a reasonable video bandwidth. The gain bandwidth specifications for the opamps are with a 2K load. Hence the gain setting resistors are 2K and 3.9K, yielding a 1.8X gain. As each inverter stage was added, the detector diode had to be reversed to maintain an output signal with negative going sync tips. The last video stage is a bit different.

Driving a 75 Ohm cable is not as simple as it seems. Many experimenters arbitrarily couple the output from an opamp, TTL gate, or a transistor switch to a coax cable and expect everything to work fine. Some times things work, sometimes they do not. Driving low impedances with gates, opamps, or switches can cause oscillations and ghosts from echoes. I selected the LH0002 because the chip is designed to drive coax cables and I had salvaged a number of them from discarded circuit boards. The input impedance is high, 400K, and the output impedance is low, only 6 Ohms. The gain is close to unity and the bandwidth is dc to 50 MHz. One oddity is the dual in line package has only 10 pins. A regular 14-pin integrated circuit socket was cut down for this application. The LH0002 is nested in the feedback loop of the last video amplifier.

The video level meter is a simple peak reading voltmeter with a relatively long time constant RC filter. The meter is used to verify the presence of a signal and to give indication when the monitor is being over or under driven. Because the sync pulses are so much shorter than the rest of the each video line, the negative peaks are a more sensitive indication of video level than the positive peaks for an ac coupled video signal. The compact meter movement is a 100 microampere full scale sensitivity military surplus meter having an arbitrary scale. The video level meter is bridged across the video output terminal which is capacitive coupled to the driver output. There is a 1K resistor across the video output pin to assure the output is always terminated and to provide a dc return for the detector. The meter rectifier is a common 1N914. The meter filter capacitor is 22uF and the series multiplier resistor is 3K. The resistor was selected so the meter reads mid-scale for a video level of approximately 1Vpk-pk.

The video detector, video amplifier chain, output driver, and level meter are all wired on a Radio Shack circuit board (part no. 276-170), which is laid out to mirror the prototyping boards.

I find enclosing a project in a metal case serves many purposes. First, the completed instrument is shielded from the influences of external RF sources. Second, the circuit radiates less RF noise. Third, there is less chance from stay wires or dropped tools shorting out or damaging components. Forth, I find that bread or brass board projects disappear after a while as components and modules are borrowed for other tests or projects. And last, the end result looks more professional. Visitors to your lab or work area are more impressed with a clean design than a rats nest. More care with the enclosure implies, but does not necessarily indicate, more care in the circuit design.

Metal cabinets are preferable over plastic not only because of their superior RF shielding, but the ability to use the surfaces as heat sinks. I have seen too many projects burn up because a plastic case was used and there was no route for the internally generated heat to escape. Circuits that operated without problem outside the case could overheat when enclosed in a plastic case. Unfortunately, it seems putting everything in a box takes longer than making the circuit and the price of a suitable enclosure can exceed the price of the components. Many of my hamfest and auction purchases are not for a piece of equipment par say, but for its cabinet or components. An enclosure was selected, cleaned, labeled with dry transfer decals, and given a protective overcoat of clear spray lacquer. A Timex/Sinclair TS-1000 label was carefully peeled from the case of a defunct computer and was applied to the front panel. A three wire ac power connector was added along with an on-off switch, fuse holder, and LED pilot light. The RF input is via a type N connector to differentiate the input connector from the BNC video output connector. The meter and level control were added. Internally, there is a brick style dual 15V power supply rated for 300mA. The RF amplifiers draw a total of 130mA from the +15V bus and the video amplifiers collectively draw a total of 47mA from each buss. To better balance the loads on the power supply busses, the LED panel light is powered from the -15V buss. Please see the attached photographs. The schematic of the completed instrument is shown in Figure 1. Not shown in the schematic is the 0.1mF bypass capacitors placed at every integrated circuit pin that connects to a buss. Also not shown is the power supply and support wiring.

The end result is a nice looking, functional RF to video converter that has found application to my retro Timex/Sinclair TS-1000 computers. The only adjustment needed is to set the level control. The instrument should work equally well with other computer devises having an RF output. The project is not meant to be directly copied using the exact same parts, but illustrates the design process. The choice of components was driven by my junk box. The design went through many changes and iterations before being declared useable. Feel free to substitute with what you have available and to experiment. Reading followed by experimentation is perhaps the best way to learn.

As with most projects on my to-do list, my only wish is that I had built it sooner. Now, it is back to the books to refresh my memory on Z80 machine language programming.

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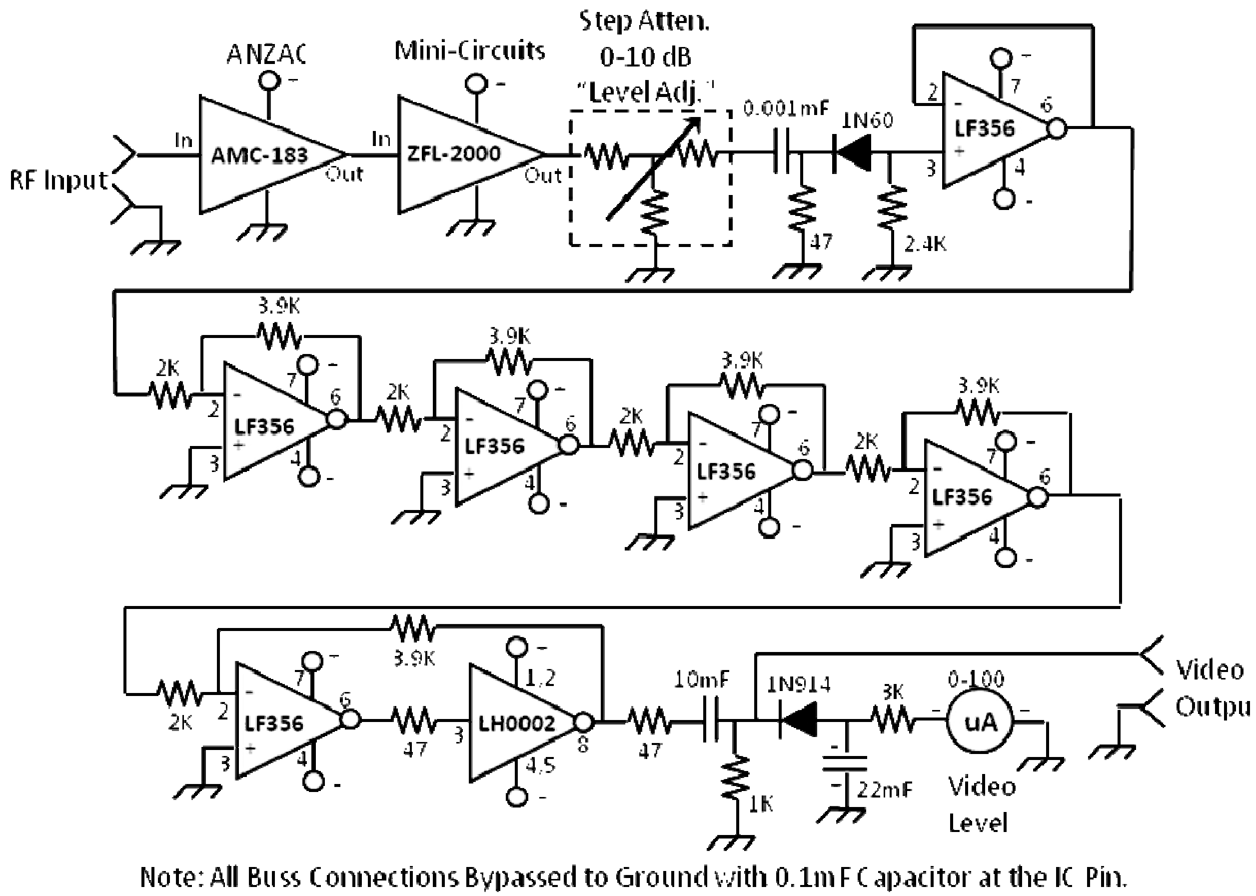

Figure 1: Schematic of RF to Video Converter

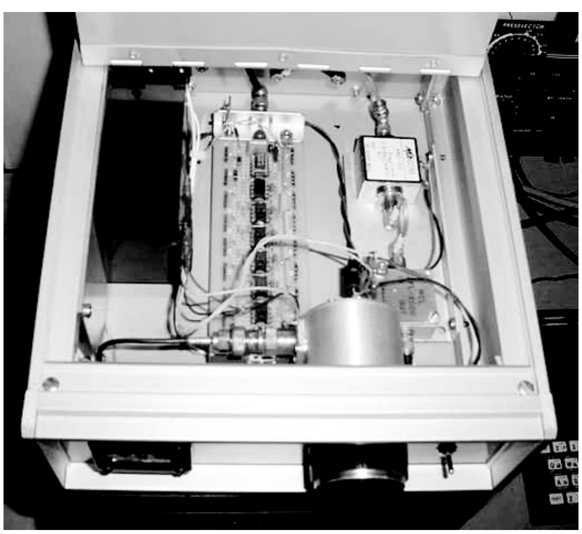

Photo A: Interior View of Converter

Photo B: Converter atop Monitor beside TS 1000