□□□□□□ **TFY Inc.** □□□□□□

The Project:

Low cost Audio-Video Modulator and Transmitter

Presentation on: Wednesday, May 10, 2000

Prepared for: Marketing Committee

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Executive Summary

Summary of Introduction: Although the current market provides devices to transmit Audio-Video (A/V) signals, they are pricy, such as $99.99 / unit, but our device can provide an inexpensive solution.

Conclusions/Recommendation: We researched and found the bright market opportunity. As our company has not been pioneered this wireless A/V market, we saw an opportunity for our company to step in, offer a low-cost (retail price of $20.00 / unit instead of $99.99 / unit from Radio Shack A/V Link) yet reliable device for A/V modulator and transmitter with quality, and affect our profitability positively.

Research Method: Not only we conducted personal interviews with highly regarded personnel in the industry, but also we gathered data through reputable periodicals (see References).

Purpose: In order to pioneer in new market and impact our profitability, our company must step in by offering a low-cost A/V modulator and transmitter.

Benefits:

The result of authorizing this project will provide consumers a low-cost method of transmitting an A/V signal from the satellite receiver or other A/V source to a TV in another room, even through walls, while reducing the restriction of cables in a household.

Practical Applications:

1. A video signal modulator to interface A/V cable to TV:

   - ✓ video camera
   - ✓ video game system

2. Security and Surveillance:

   - ✓ baby monitor (in conjunction with a camcorder)

3. A wireless connection between VCR and TV:

   - ✓ Remove VCR applications

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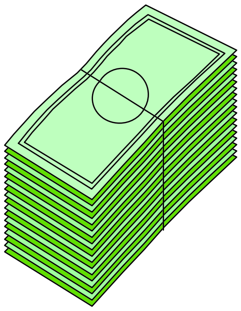
Introduction:

This report, ***Low cost Audio-Video Modulator and Transmitter***, was authorized by Chris Wilson on December 18, 1999.



The current market contains few low-cost devices available to transmit audio-video signals. In order to serve consumers and for us to pioneer new market, we built a cost-effective device which will lead to increase in our company's profitability.

Our device will take a separate audio and video signal, modulate them into a television signal, and transmit the signal so that ***any*** unmodified television receiver could receive the signal.

In this document, we will explain about:

- ✓ cost comparison
- ✓ performance comparison
- ✓ benefit and marketable features.

Because our device is for ***domestic*** household use only, it compiles with the local telecommunications authorities (or for a Class B digital device as specified in Part 15 of Federal Communication Commission FCC rules - see references)

This report begins with a series of conclusions and recommendations, discusses what distinguishes our device from other products, and concludes with a summary of benefits.

Conclusions:

✓ ***Low-Cost*** In our project, we have proved that our device can be constructed with low-cost. The table of comparisons provided a clear distinction between our device to others.

$20.00 (Estimated Retail Price)	**Our *Low-Cost Audio-Video Modulator/Transmitter***	**TFY Inc.**

Price in $CDN (as of May 2, 2000)	**Products in Current Market**	**Company**
$57.99		Quality Kits 49 McMichael Street Kingston, ON K7M 1M8 Canada www.qkits.com/
$99.99		RadioShack www.radioshack.com/

N.B. Above products provide similar features and compactness as our device. However, both consist of significant amounts of components being utilized which are more costly. Also, the increase in cost is proportional to the type, the design, and material of packaging.

✓ ***High Performance***

Like other products, our modulator provides a high quality picture and audio signal. Also, the modulator is a mini-transmitter by connecting it to a small antenna. It is possible to receive the video recorder or camera in a different part of the house (15 meters range approx.)

✓ ***Benefits***

Low-cost Audio-Video Modulator/Transmitter is the perfect choice for:

(A) Video Distribution:

1. View your VCR, laserdisc, satellite dish, or cable descrambler on channel 3 and broadcast it to every TV in the home

2. Display multiple video sources in household

(B) Security and Surveillance:

1. Turn your camcorder into a baby-cam and view it from any TV in the home

2. Keep an eye on children playing outside, or check on animal kennels and stables from the comfort of your home

(C) Wireless connection between VCR and TV

- ✓ Remove VCR applications
- ✓ Provide a safe, convenience, and practical connection

Discussion:

Proposed Project

As outlined in the proposal, the device we built is a low cost method to modulate and transmit a baseband audio/video signal to any television receiver. There were no changes made to the project to modify this goal. A working prototype has been built on schedule and under budget.

Applications of the Device

The device was designed to accept video and audio baseband signals from satellite receivers, video cameras, VCR's, or any compatible input device. This device is very versatile due to its ability to accept a signal from any possible number of input devices. This allows the device to be used for multiple tasks with no modifications to the device.

Common uses of this device include:

- ✓ wireless video camera, video game, or movie transmission
- ✓ wireless surveillance/ baby monitor

Since most video cameras and video game systems come equipped with baseband audio/video outputs, they can be used with our device to transmit audio/video signals to a television, over a wireless link. This reduces the need to have multiple wires connected to the television.

If only one VCR is in a household, this device will allow you to watch a video from anywhere in the house. Many households have a TV in the kitchen. Pop a recorded cooking show in the VCR and the signal will transmit to the TV in the kitchen. This allows the user to view the tape without moving the VCR.

In conjunction with a video camera, the device could be used for wireless surveillance, or a baby monitor. This would provide a economical method to ensure the security of your home or child.

This device can be used for various practical natures. With the continuing advancement of technology, many more uses will become a necessity.

Cost/Budget

All the parts used in this project were common parts, and no parts had to be ordered in special. This allowed the cost of the project to stay down. The estimated cost of the project was $4,150, but the cost of the project was $3,102. Therefore, the project was $1,048 under budget.

Technical Description

General Operation

The device is an audio-video modulator, operating in the VHF band, which provides a low cost method of transmitting an audio-video signal. The device inputs are baseband audio and baseband video signals. The separate audio and video signals are fed into the modulator circuit. The modulator circuit AM modulates the video signal and FM modulates the audio signal. These signals are combined. The RF output of the modulator is then filtered, amplified, and fed into the antenna. The transmitted signal can be received with any standard, unmodified TV receiver. The block diagram of the transmitter can be seen in Figure 1.

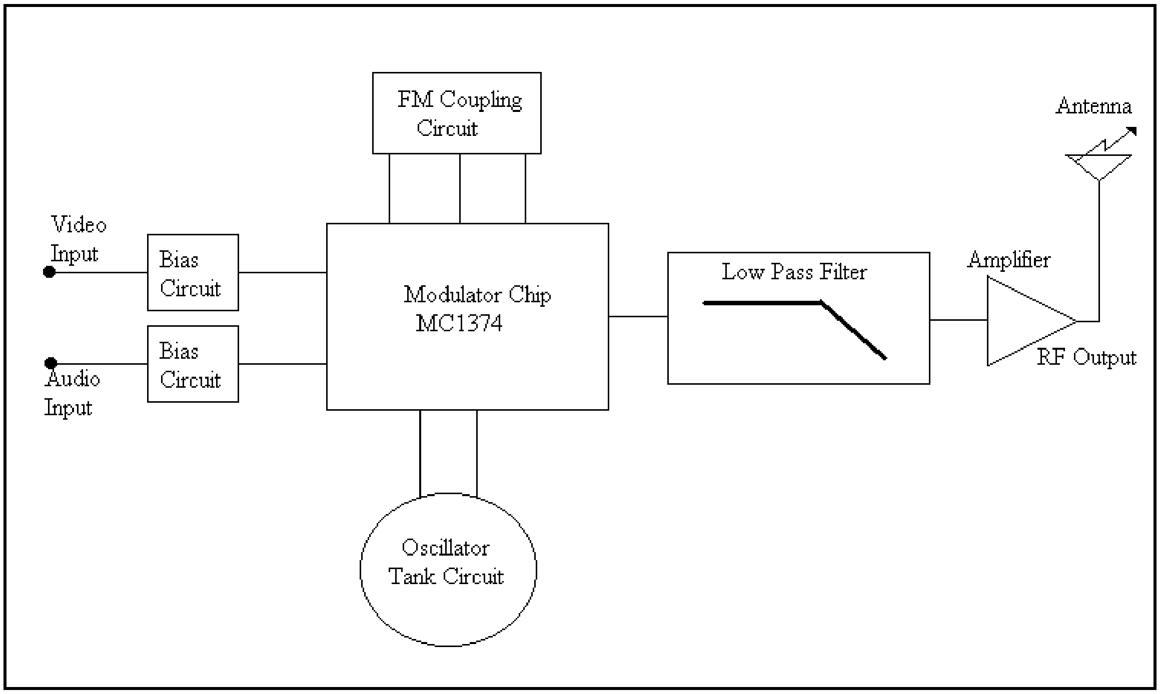


Figure 1 Block Diagram

The modulator circuit will be used to convert the audio and video baseband signals into a standard television broadcast signal corresponding to channel 3. To achieve this, the MC1374TV modulator IC will be used. The MC1374 requires a local oscillator tank circuit. The resonating frequency of the circuit determines the carrier frequency of the video signal (which is 61.25MHz for channel 3). The TV modulator IC also requires a coupling circuit to couple the FM modulated audio signal with the AM modulated video signal.

Due to the small phase errors created within the MC1374, a low pass filter is required on the output of the modulator. The small phase errors create harmonic distortion in the RF output signal and the filter is used to remove this distortion. The filter that will be used is a double-pi low pass filter.

To transmit a signal that will be strong enough for a television receiver to receive, the RF output signal must be amplified. Since the signal is to be transmitted within close proximity to the device, the output power of the antenna will only need to be around 1mW.

To receive the audio-video signal, the television receiver is tuned to channel 3. With the TV receiver tuned to channel 3 and the receivers antenna extended, the audio-video signal will be seen and heard.

Specific Operation of Blocks

Modulator

The modulator converts the base band audio/video signal to a standard NTSC TV signal, with a video carrier frequency of 61.25MHz, and an audio carrier frequency of 65.25 MHz. For reference, Appendix A shows the schematic drawing of the audio/video modulator.

Input Bias

The MC1374 requires external biasing for the modulator to operate correctly. The bias levels of the AM modulator are critical. The bias levels on pin 1 and pin 11 of the AM modulator will control the modulation depth. If the bias is not set correctly, the modulator could saturate or clip the signal, causing the output to be distorted.

The FM modulator does not require any biasing, but it is recommended for optimum performance. If no biasing of the FM modulator input is provided, it will bias itself at approximately 3.0V on pin 14. But the transfer characteristics show that this bias is a little too high for optimum modulation linearity. Thus, for optimum performance, a bias circuit will be used to bias the FM modulator input at 2.6 to 2.7V using a simple voltage divider.

AM Oscillator/Modulator

The AM system is a basic multiplier combined with an integral balanced oscillator capable of over 100MHz operation.

To generate the 61.25MHz carrier, the AM modulator requires an external oscillator circuit. The oscillator can be crystal, but a simple and cheap parallel LC oscillator was used. The LC oscillator is set to have a resonating frequency of the 61.25MHz as required by the AM modulator. It is recommended that the Q of the LC oscillator should be between 10 to 20 for stable operation. It is also recommended that the capacitance be much larger than the inductor to minimize variations in capacitance of the capacitor.

The gain of the AM system is controlled by the resistance between pins 12 and 13. This gain will be determined by the amplitude of the input signal. As a guidelines, the value of R_G should be:

$$R_G = \frac{2(peak\_video)}{1.15mA}$$

FM Oscillator/Modulator

The FM oscillator/modulator is all contained in one circuit. It consists of a voltage controlled oscillator (VCO) which exhibits an almost linear output frequency versus input voltage characteristics for a wide deviation. This provides a good FM source with very few inexpensive external parts.

The FM oscillator consists of a LC parallel resonance circuit, which acts as the oscillator of the VCO. The LC circuit is designed to oscillate at 4.5MHz, which allows for a deviation of $\pm$25kHz to be obtained. A frequency of 4.5MHz was used because the sound carrier is 4.5MHz above the video carrier.

The FM modulated, audio output signal, is coupled, through a capacitor, to the AM modulators bias on pin 1. The modulated audio signal is then added to the modulated video signal and the output appears on pin 9. When the two signals are summed together, the 4.5MHz audio signal is added to the 61.25MHz video signal, which produces the 65.25MHz sound carrier.

Filter

Due to the small phase errors created within the MC1374, a low pass filter is required on the output of the modulator. The small phase errors create harmonic distortion in the RF output signal and the filter is used to remove this distortion.

The filter that is used is a double-pi, low pass filter. The double-pi filter is a cheap and effective way of removing the second harmonic distortion from the output of the modulator. It is relatively lossless, and has a very flat frequency response in the pass band, which is very important for an AM modulated signal.

Amplifier

The amplifier is used to amplify the low level signal from the modulator so it can be transmitted over a wireless link. The amplifier required to do this job must have a wide bandwidth and have a very linear performance.

The amplifier that was chosen for this task was the NE5205 wideband amplifier. It has a gain of approximately 20dB, and operates in a frequency range from dc to 500MHz. This amplifier was chosen because it was built and tested in a lab, so time could be saved using this amplifier instead of finding a new amplifier, building it, and then testing it.

The NE5205 has all the requirements, so there should be no problems using it for this application.

Antenna

The antenna being used for this system is a tight wound antenna. By using a tight wound antenna, the overall length of the antenna can be reduced substantially.

If a quarter wavelength whip antenna was used, it would be 1.2 meters long, but by using a tight wound antenna, the antenna length can be reduced to 28 centimeters. The tight wound antenna acts like a loading coil, which increases the effective length of the antenna. It is due to this property that the antenna length can be reduced.

Milestones

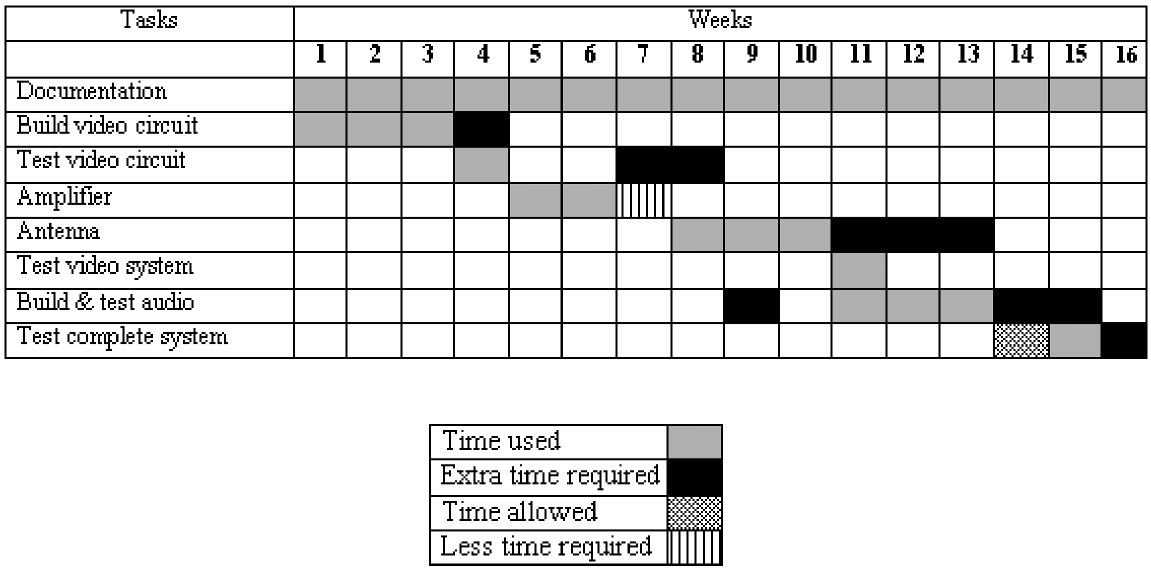


Figure 2 Milestone Chart

As it can be seen in Figure 2, all the tasks for this project have been completed on time, as well as under budget.

Not all the tasks were completed as anticipated. The video circuit required more time to build since all the inductors were hand wound on toroid cores. Since the amplifier was built and tested in a lab, this task was completed ahead of schedule. The antenna also took longer to design and build due to required impedance measurements. The audio circuit also took longer to get operation. This was due to a problem with the audio LC oscillator. The oscillator would not start oscillating. The problem was fixed by replacing the molded inductor with a toroid wound inductor.

Advantages/Disadvantages

Advantages

An advantage of this device is that it is easy to use, as discussed in more detail later on in this document. The device is also light weight and compact making it easy to transport, and does not take up much space. Finally, the biggest advantage of the device is its cost. At a retail price of approximately $30, you will not find a cheaper video transmitter.

Disadvantages

The disadvantage of this device is that it is not secure. Anyone within receive distance of the device can view your transmission. Another disadvantage is that the device can only modulate and transmit a single audio/video signal at a time. Thus, you have to transmit the same signal to all the receive tv's, you cannot send multiple signals destine for different computers.

Users Guide

To use this device is relatively simple. To transmit a signal, all that has to be done is, supply power to the device and connect the audio and video input signals to the RCA jacks on the device. Once the input signals are connected, and the power is on, the device is modulating and transmitting.

To receive the signal, the television has to be tunned to channel 3 and the antenna on the tv extended. Tune the antenna until the picture comes in clear and that is it. You can now view the video signal you are transmitting.

Figure 3 shows some common configurations using the device.

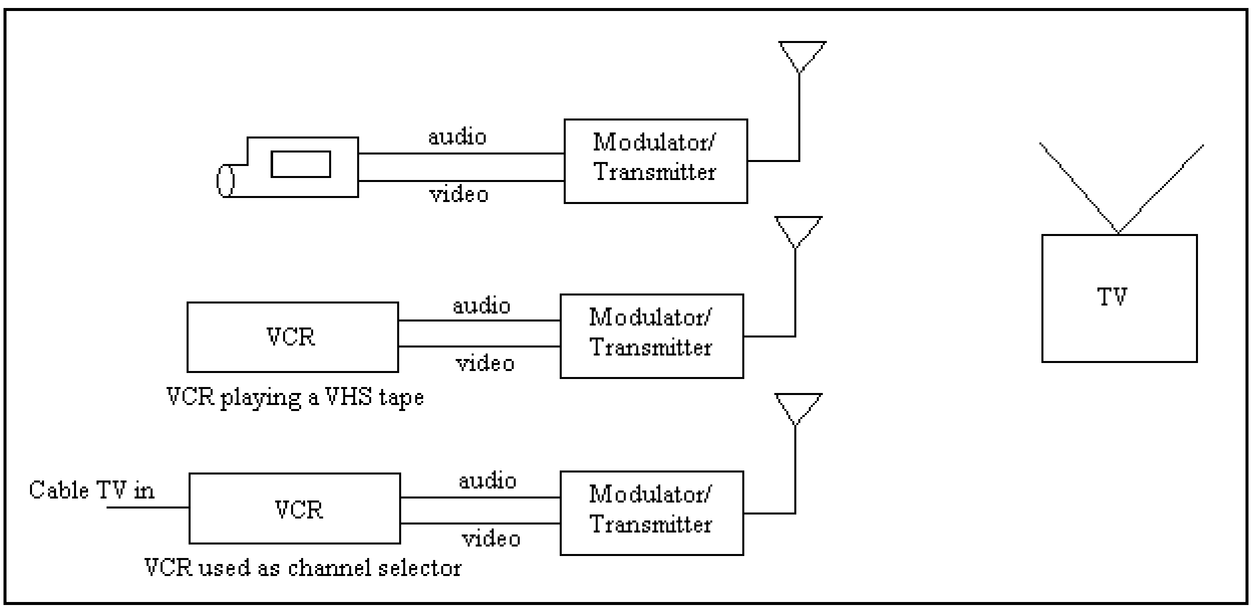


Figure 3 Common Setup Configurations

Recommendations

With the prototype functioning, the next possible area of study would be to insert a radio system to carry the signal to the television set. This would require both a transmitter and receiver module. Having both a transmitter and receiver would increase the cost of the device, but by using a radio system, the signal could be secured so it could not be intercepted and viewed by someone else. It would also all for the flexibility needed so that the device could be used in commercial applications as well as domestic.

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Appendix A

Schematic Drawings

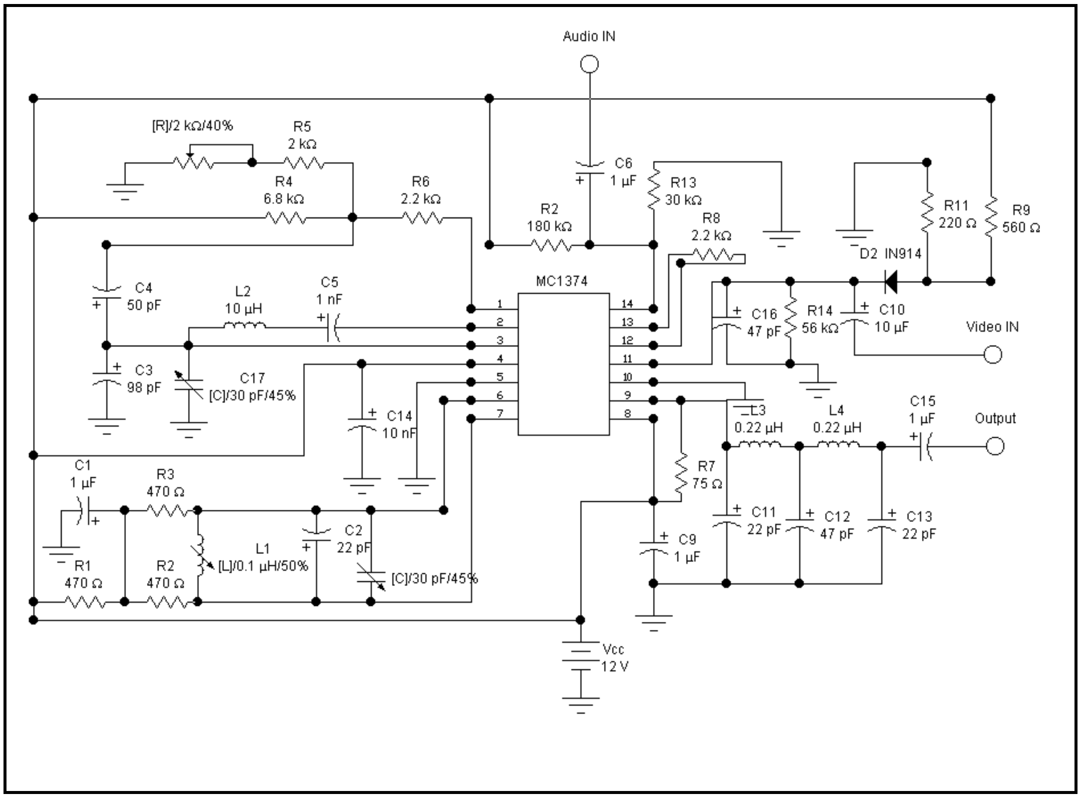

Figure 4 Schematic Diagram of the Modulator

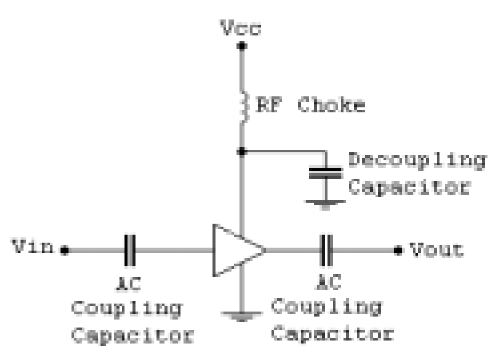

Figure 5 Schematic Diagram of the Amplifier

Parts List

Description	Quantity	Reference ID
MC1374	1	U1
10µH Inductor	1	L1
0.22µH Inductor	2	L4, L3
0.1µH Inductor	1	L2
10nF Capacitor	1	C2
10µF Capacitor	1	C18
22pF Capacitor	3	C6, C12, C15
1µF Capacitor	4	C8, C19, C16, C11
50pF Capacitor	1	C3
98pF Capacitor	1	C4
47pF Capacitor	2	C14, C17
1nF Capacitor	1	C1
1kΩ Potentiometer	1	R7
2.2kΩ Resistor	2	R14, R1
2kΩ Resistor	1	R6
470Ω Resistor	3	R4, R2, R9
560Ω Resistor	1	R12
220Ω Resistor	1	R13
56kΩ Resistor	1	R11
180kΩ Resistor	1	R16
6.8kΩ Resistor	1	R8
30kΩ Resistor	1	R15
75Ω Resistor	1	R3
30pF Variable Capacitor	2	C7, C5

Appendix B
Design Calculations

This appendix will cover the design calculations used. The designs covered are the inductor, antenna, and the antenna matching circuit designs.

Inductor Designs

Inductor L1, L3 and L4 (using Miller powdered Iron Toroidal core T25-12 with AWG#24 copper wire)

$$N = \#\text{ of turns} = 100 \times \sqrt{\frac{\text{desired L}[\mu H]}{A_L[\mu H / 100 \text{ turns}]}}$$

where :

t = turns

A_L = Toroid Index = 12.0 [μH / 100 turns]

For L1 = 0.1 [μH];

$$N = 100 \times \sqrt{\frac{0.1[\mu H]}{12.0[\mu H / 100 \text{ turns}]}} \cong \underline{\underline{9.13 \text{ [turns]}}}$$

For L3 & L4 = 0.22[μH] (AWG #28);

$$N = 100 \times \sqrt{\frac{0.22[\mu H]}{12.0[\mu H / 100 \text{ turns}]}} \cong \underline{\underline{13.5 \text{ [turns]}}}$$

Inductor L2 (using Ferrite 4C4 Toroidal core with AWG#20 copper wire)

$$N = \#\text{ of turns} = \sqrt{\frac{\text{desired L}[\mu H]}{A_L \times 10^{-3}}}$$

where :

A_L = Toroid Index = 70

For L2 = 10[μH];

$$N = \sqrt{\frac{10\mu H]}{70 \times 10^{-3}}} \cong \underline{\underline{11.95 \approx 12[\text{turns}]}}$$

Antenna Design

This design is for a tight wound antenna operating at 63MHz.

$$C_A = \frac{17l}{\left[\left(\ln\frac{24l}{D}\right)-1\right]\left[1-\left(\frac{fl}{234}\right)^2\right]}$$

CA = capacitance of the antenna (pF)

l = antenna height (ft)

D = diameter (inches)

f = frequency (MHz)

For the designed antenna:

It was recommended that the length of the antenna be l=0.05λ

f=63MHz

The diameter of the antenna was chosen to be 1.6cm since the dowel to be used as a form to wind the antenna on, would form an antenna diameter equal to this

D=1.6cm=0.630 inches

$$\lambda = \frac{c}{f} = \frac{3*10^8}{63*10^6} = 4.76m$$

$$l = 0.05\lambda = 0.05(4.76) = 23.8cm = 0.781ft$$

$$C_A = \frac{17l}{\left[\left(\ln\frac{24l}{D}\right)-1\right]\left[1-\left(\frac{fl}{234}\right)^2\right]}$$

$$= \frac{17(0.781)}{\left[\left(\ln\frac{24(0.781)}{0.630}\right)-1\right]\left[1-\left(\frac{(63)(0.781)}{234}\right)^2\right]} = 5.81\,pF$$

Since the inductance of the coiled antenna must equal the capacitance of the antenna to ground to cause resonance, the coil inductance equals:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$L = \frac{1}{C(2\pi f)^2} = \frac{1}{5.81\text{pF}(2\pi(63\text{MHz}))^2} = 1.10\,\mu\text{H}$$

Since the antenna is air wound, the inductance of a air wound coil is given by the equation:

$$N = \sqrt{\frac{L(22.9l + 25.4r)}{r^2}}$$

where:

N = number of turns

l = length of coil (cm)

r = radius of coil (cm)

L = inductance of coil (µH)

The values of l and r are the same as used above in calculating the capacitance of the antenna and L was calculated to be 1.27 µH.

l=23.8cm

$$r = \frac{D}{2} = \frac{1.6}{2} = 0.8cm$$

L=1.27 µH

$$N = \sqrt{\frac{L(22.9l + 25.4r)}{r^2}}$$

$$= \sqrt{\frac{(1.1)(22.9(23.8) + 25.4(0.8)}{(0.8)^2}} = 31turns$$

Therefore, the antenna dimensions are:

diameter = 1.6 cm

length = 23.8 cm

number of turns = 31 turns

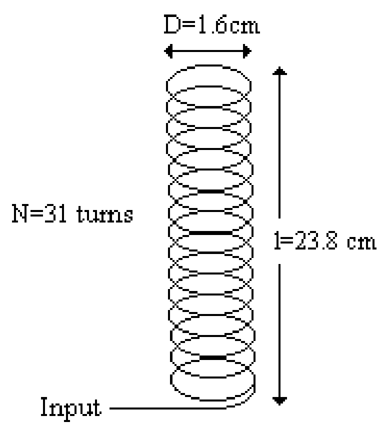

Figure 6 Antenna Design

With no matching, the reflection coefficient would be:

$$\Gamma = \frac{Z - Z_O}{Z + Z_O} = \frac{164 - 75}{164 + 75} = 0.372$$

which is a return loss of

$$20 \log \Gamma = 20 \log(0.372) = -8.58 dB$$

To match the input impedance of the antenna to the output impedance of the amplifier, a LC matching circuit will be used. The output impedance of the amplifier is 75 ohms and the input impedance of the antenna was measured to be 164 ohms. To match these impedances, the following LC matching circuit was used.

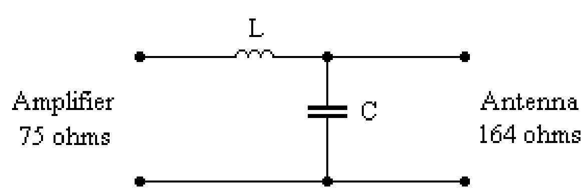

Figure 7 LC Matching Network

$$Q = \sqrt{\frac{R_p}{R_s} - 1} = \sqrt{\frac{164}{75} - 1} = 1.09$$

$$Q = \frac{\omega L}{R_p} = R_s \omega C$$

$$L = \frac{Q R_p}{\omega} = \frac{(1.19)(164)}{2\pi(63MHz)} = 0.451\mu H$$

$$C = \frac{Q}{R_s \omega} = \frac{1.19}{(75)2\pi(63MHz)} = 37pF$$

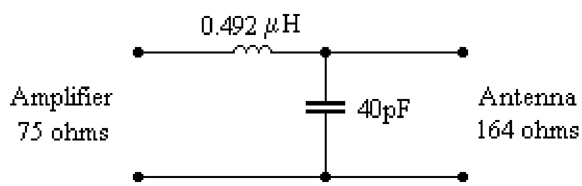

Figure 8 LC Matching Circuit Design

Appendix C

Modifications to Application Note AN-829 Design

This appendix will cover the modifications that were made to the TV modulator design given in Motorola's application note, AN-829.

Video Oscillator

A modification was made to make the LC oscillator that is used for the video modulator adjustable. To do this, a small 3 to 30 pF capacitor was placed in parallel with the capacitor of the LC oscillator, as shown in Figure 9. This allows the capacitance of to be adjustable which will change the oscillators frequency.

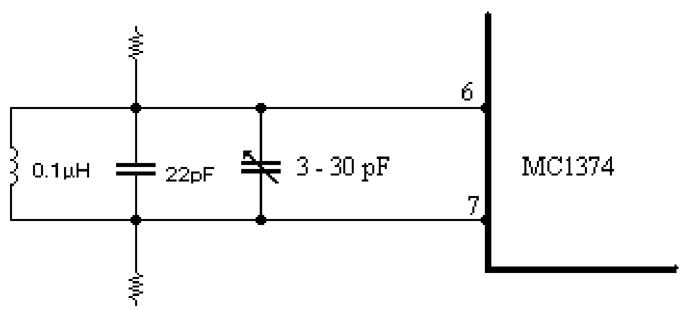

Figure 9 Video Oscillator Modification

The audio oscillator was also made variable so the oscillators frequency could be tuned more easily. A 3 to 30 pF tuning capacitor was used again for this job as seen in Figure 10.

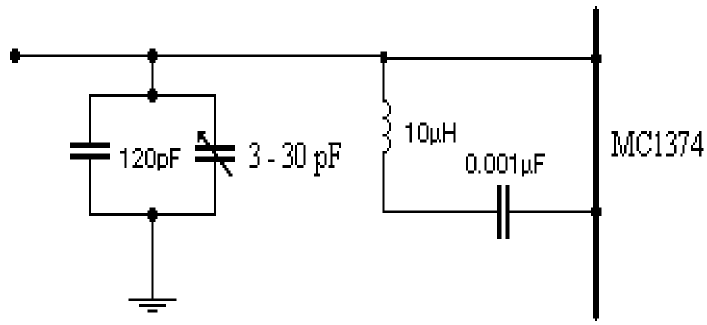

Figure 10 Audio Oscillator Modifications

An interesting note about the audio oscillator is that it would not oscillate if a manufactured, molded inductor was used. Once the molded inductor was replaced with a wound toroid core inductor, the oscillator oscillated perfectly. This seems odd, and the reason for this should be investigated. This was not investigated, as yet, due to lack of time.

Bias of Pin 1

The bias on pin 1 was made variable, with a 2k ohm potentiometer. This was done so that the effects of this bias voltage on the modulator could be monitored. The modified voltage divider used to supply the bias voltage to pin 1 can be seen in Figure 11.

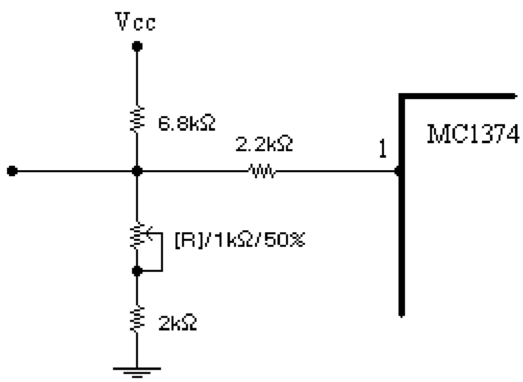

Figure 11 Pin 1 Voltage Divider Modification

Audio Input Attenuation

The baseband audio input into the modulator was 2Vp-p, but the FM modulator only operates linearly for input voltages up to 1Vp-p. Thus, the audio input signal need to be attenuated slightly. To do this, a 150 ohm resistor was placed from the input of the modulator to ground. This effectively reduced the amplitude of the audio input signal so the FM modulator would operate within its linear range of operation. The modification can be seen in Figure 12.

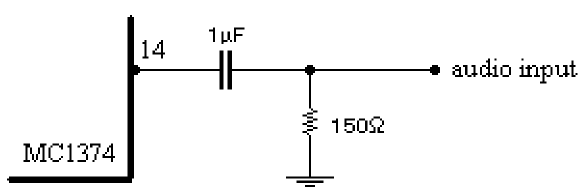

Figure 12 Audio Input Attenuation

Appendix D

Test Procedures and Results

This appendix will discuss all the test procedures performed on the device. The tests performed include a linearity test of the video modulator, and input impedance of the antenna.

Video Modulator Linearity

The linearity of an AM modulator is crucial for its proper operation. A linear modulator will have an equal change in output voltage for an equal change in input voltage. Thus, if a plot of output voltage verses input voltage is plotted, the result will be a straight line for a linear modulator, where the slope of the line is the gain.

The test setup used to test the linearity of the video modulator is given in Figure 13.

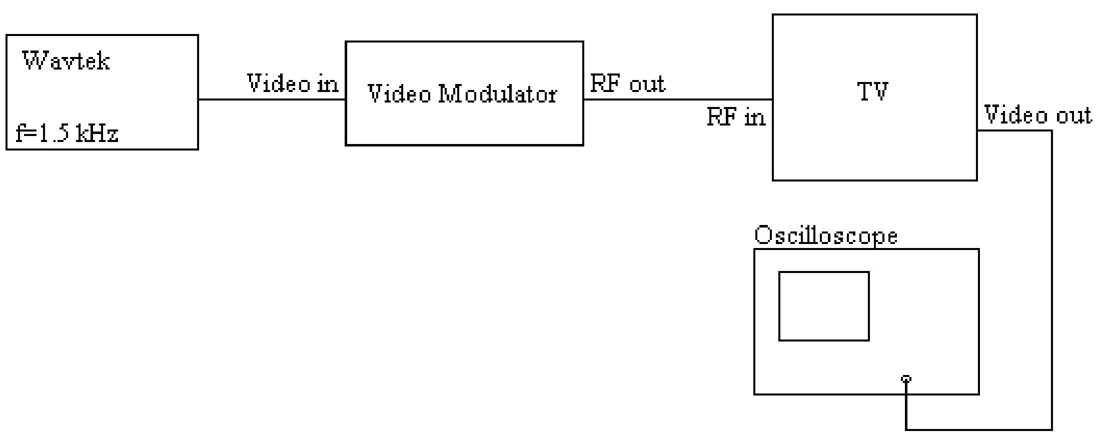

Figure 11 Video Modulator Linearity Test Setup

To measure the linearity, the function generator was set to 1.5kHz and the output voltage plotted for several input voltages. The resulting data and plot can be seen in Table 1 and Figure 14.

Table 1 Linearity of the Video Modulator

Input Voltage (Vp-p)	Output Voltage (Vp-p)
0.05	0.035
0.10	0.06
0.15	0.13
0.20	0.21
0.25	0.30
0.30	0.37
0.35	0.44
0.4	0.54
0.5	0.70
0.6	0.88
0.7	1.04
0.8	1.18
0.9	1.32
1.0	1.48
1.1	1.6
1.2	1.8
1.3	1.9
1.4	2.0
1.5	2.0
1.6	2.0
1.7	2.0
1.8	2.0

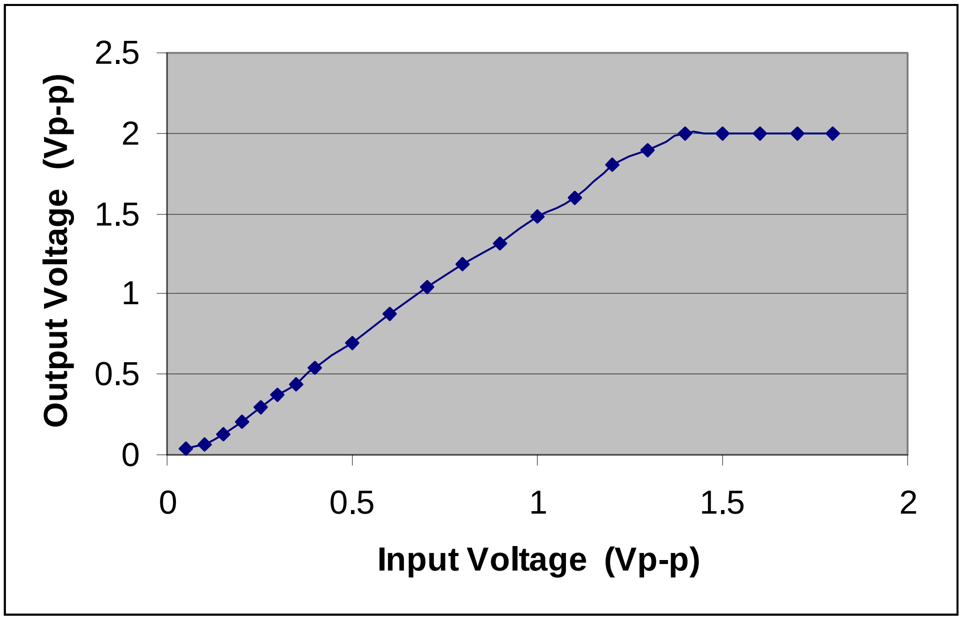

Figure 14 Video Modulator Linearity

The flattening of the gain at 2Vp-p is probably due to the voltage limiter at the output of the tv, since the maximum output voltage of the audio output on the back of the tv is rated at 2Vp-p. From Figure 14, it can be seen that the video modulator is fairly linear throughout its operating voltages.

Input Impedance of the Antenna

To determine the input impedance of the antenna, the setup seen in Figure 15 was used.

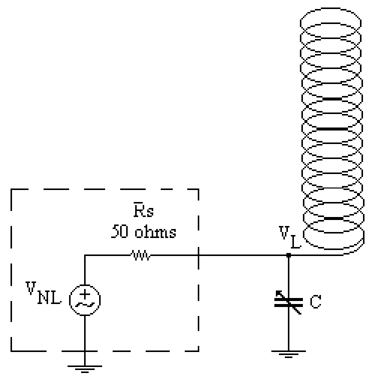

Figure 15 Antenna Input Impedance Test Setup

Using the setup seen in Figure 15, it was first determined if there was any reactive component to the impedance of the antenna. By design there should be no imaginary component to the impedance, it should just be real. When the capacitor was place into the system as shown in Figure 15, the magnitude of the voltage across the antenna dropped. This would mean that the input impedance was not capacitive. An inductor was then placed in series with the antenna, and again the voltage dropped. Thus, there must be no imaginary component to the impedance of the antenna.

The resistance of the antenna was determined by first measuring the no load voltage of the source and then measuring the loaded voltage of the source. The resistance of the antenna is then given by the equation:

$$R_a = \frac{R_s V_L}{V_{NL} - V_L}$$

The measured values were:

VL=2.3V

VNL=3.0V

$$R_a = \frac{(50)(2.3)}{3.0 - 2.3} = 164\Omega$$

Thus the input impedance of the antenna was measured to be 164Ω.