Application Report

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AN-1822 LMH6733 High Definition Video Transmission Over CAT5

ABSTRACT

Sending component 1080i high definition (HD) video over CAT5 twisted-pair is achievable with a low-cost solution using Texas Instruments current feedback (CFB) LMH6733 operational amplifier. The LMH6733 is a triple operational amplifier with disable that has a slew rate of 1900 V/µs and a 2 V_{PP} output signal bandwidth of 480 MHz, making it ideal for this application. Component video signals are made up of luma (Y) signal that contains the brightness and synchronizing information, and the two color-difference signals Pr and Pb.

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1 Introduction

Standard CAT5 cable consists of 4 twisted-pairs of AWG-24 cables with characteristic impedance of 100 Ω. The DC resistance is 10 Ω/100m and capacitance of 4.5 nF/100m. Attenuation within CAT5 cable increases exponentially with respect to cable length and is a concern that will be addressed with equalization. Figure 1 illustrates this loss at various cable lengths.

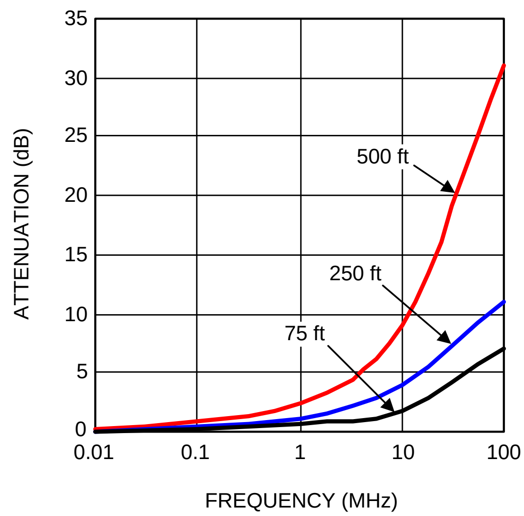


Figure 1. CAT5 Cable Attenuation

By utilizing 3 of the 4 twisted-pairs, the entire signal path can be designed using the LMH6733 amplifier for the driver, receiver, and equalizer circuits to drive 75 ft, 250 ft, and 500 ft of CAT5 cable. Figure 3 shows the block diagram consisting of all three circuit sections. Each circuit section will be explained in further detail in this application report

2 Video Transmitter

The video transmit board has one LMH6733 device configured to drive component video input from an HD video source onto selectable CAT5 cable lengths of 75 ft, 250 ft, and 500 ft. The cable length select switch is located on the video receive board. Figure 2 shows one channel of the LMH6733 configured for a gain of 2 V/V to drive one CAT5 twisted-pair. The 50 Ω output series resistor isolates the device from the long CAT5 transmission twisted-pair with one of the wires connected to ground through a 50 Ω resistor to balance the load.

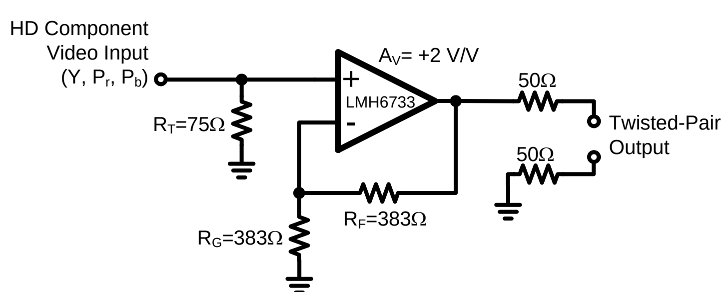


Figure 2. Twisted Pair Video Driver

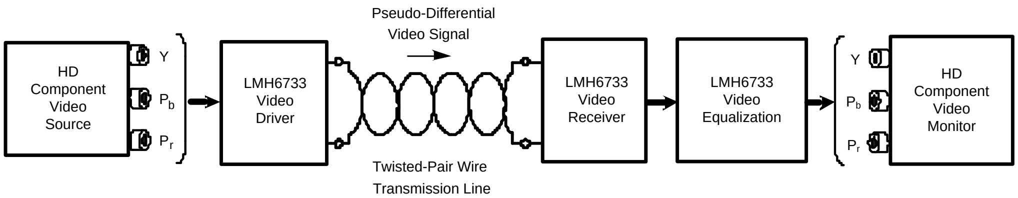


Figure 3. Video Transmission Block Diagram

Figure 4 shows the video transmit reference design board with a RCA connector for connecting the 1080i video source and a RJ45 connector to connect the CAT5 cable. The board has several options to apply power. For more details, see Section 4.

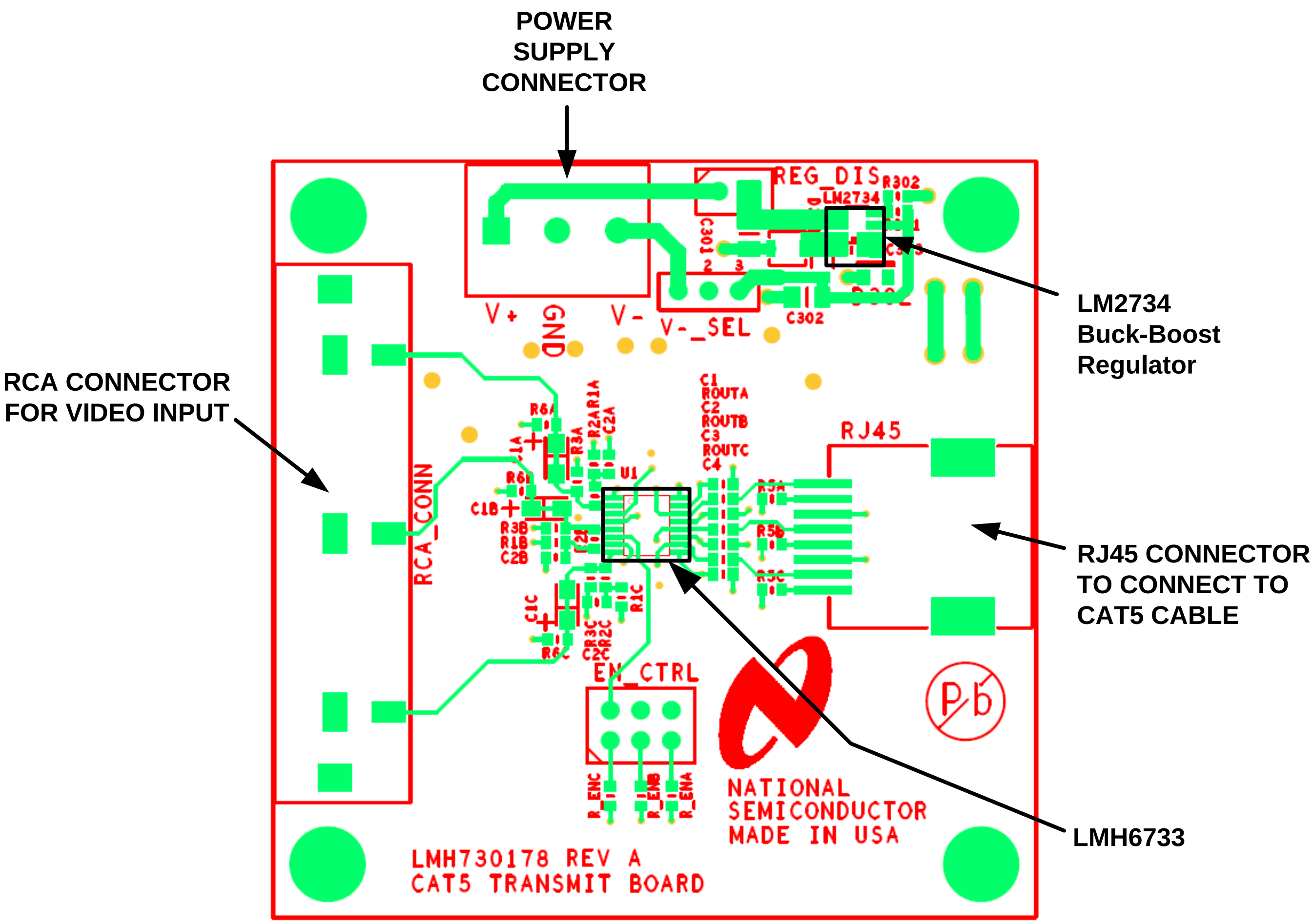


Figure 4. CAT5 Transmit Board

3 Video Receiver and Equalization

The video receiver board has one LMH6733 device to function as a differential input signal receiver and three additional LMH6733 devices to perform signal equalization for cable lengths of 75 ft, 250 ft, and 500 ft. Each channel of the LMH6733 receiver device is configured for a gain of −2 V/V to handle a differential input signal from the three twisted-pairs for the Y, Pr, and Pb video signals. A first order RC, low-pass filter with a −3 dB roll-off of 200 MHz is place between the receiver output and equalizer input to filter out high frequency noise components.

Due to the non-inverting input capacitance of 1 pF, an inverting gain topology is recommended for the equalization circuit to minimize gain peaking and potential oscillation due to excessive parasitic capacitance and inductance associated with device package and board routing. The equalization circuit is implemented with an additional LMH6733 channel along with a network of RC branches in parallel with the gain resistor, R_G, to provide a zero-pole compensation for attenuation of higher frequency signals in the CAT5 twisted-pair wires. Each branch compensates for the set frequency of attenuation depending on the cable length, such that the video signal maintains a flat frequency response to accommodate the 31 MHz of large signal bandwidth required for 1080i HD signal. For example, to transmit HD video signal up to 500 ft of CAT5 cable the three set frequencies are approximately 2.5 MHz, 9 MHz, and 31 MHz, respectively. Because of its high slew rate value, the advantage of using CFB amplifiers as the equalizer is its ability to boost equalization gain at high frequencies. The output of the equalizer drives a R_O = 75 Ω load to match the input impedance of the video display. Figure 5 shows the circuit implementation of one receive channel driving one equalization channel.

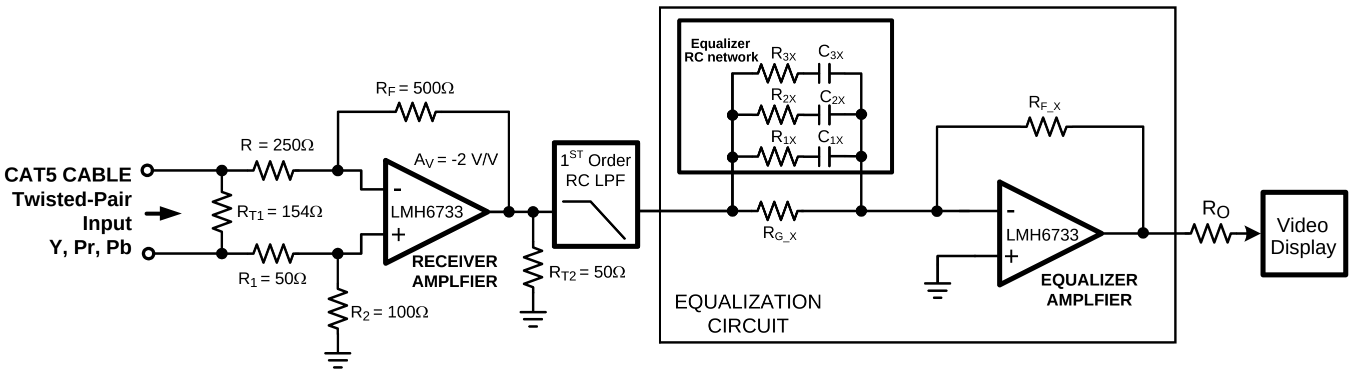


Figure 5. CAT5 Video Receiver and Equalization Circuit

Figure 6 shows the details of the equalization circuit configured to equalize one of the component video signals Y, Pr, or Pb. However, the entire equalization circuitry is made up of three LMH6733 devices for Y, Pr, and Pb signals and is shown in Figure 7. Each channel of the LMH6733 is optimized through the RC network to drive CAT5 cable lengths of 75 ft, 250 ft, and 500 ft.

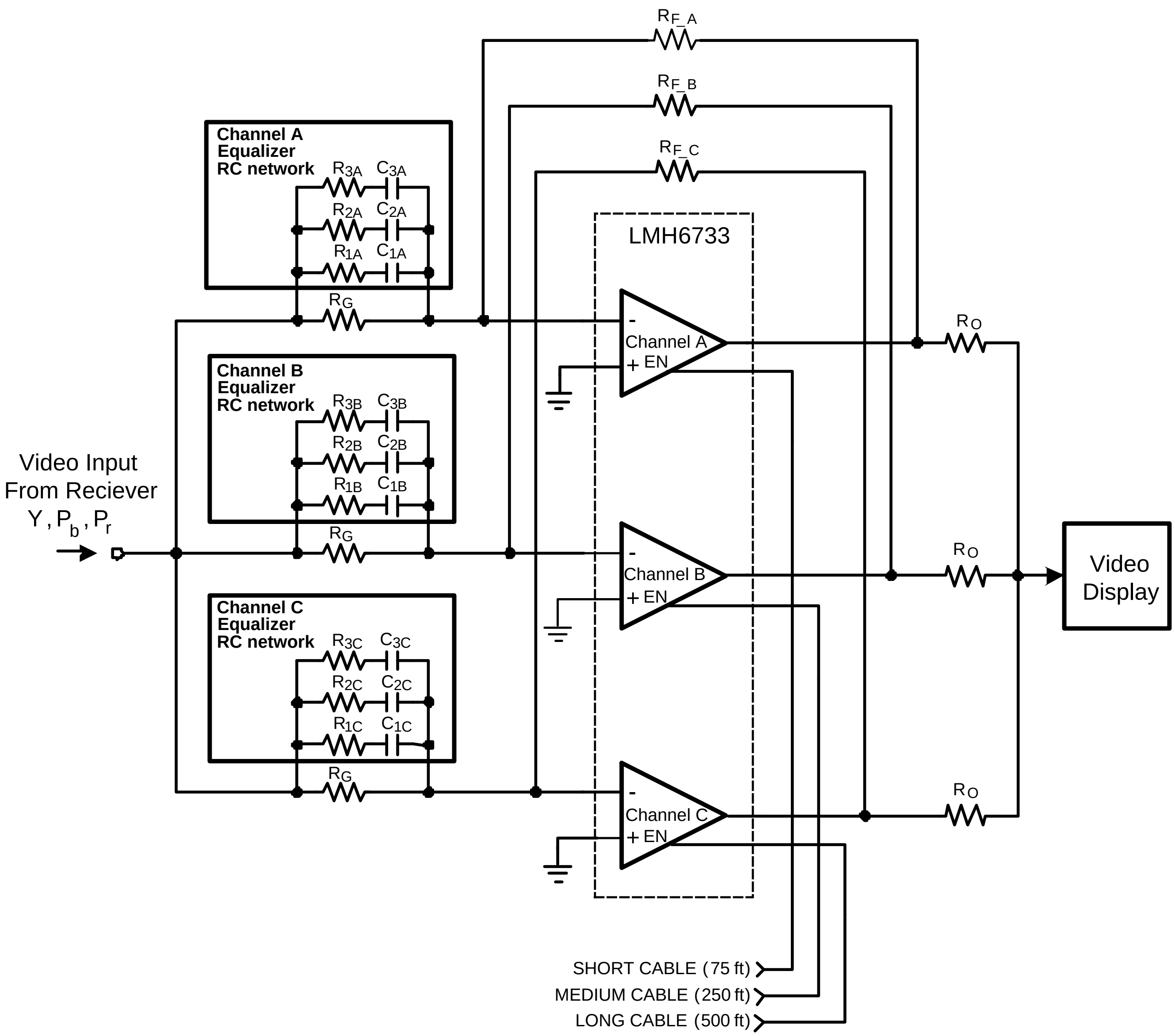


Figure 6. Equalization Circuitry for Various CAT5 Cable Lengths

Table 1. RC Network Equalization Table

RF	RG	Channel A: 75 ft CAT5		Channel B: 250 ft CAT5		Channel C: 500 ft CAT5	
550 Ω	383 Ω	R_{1A} = OPEN	C_{1A} = OPEN	R_{1B} = 200 Ω	C_{1B} = 68 pF	R_{1C} = 25 Ω	C_{1C} = 120 pF
		R_{2A} = OPEN	C_{2A} = OPEN	R_{2B} = 1.35 kΩ	C_{2B} = 1.5 pF	R_{2C} = 700 Ω	C_{2C} = 1.8 pF
		R_{3A} = OPEN	C_{3A} = OPEN	R_{3B} = 8.4 kΩ	C_{3B} = 18 pF	R_{3C} = 909 Ω	C_{3C} = 47 pF

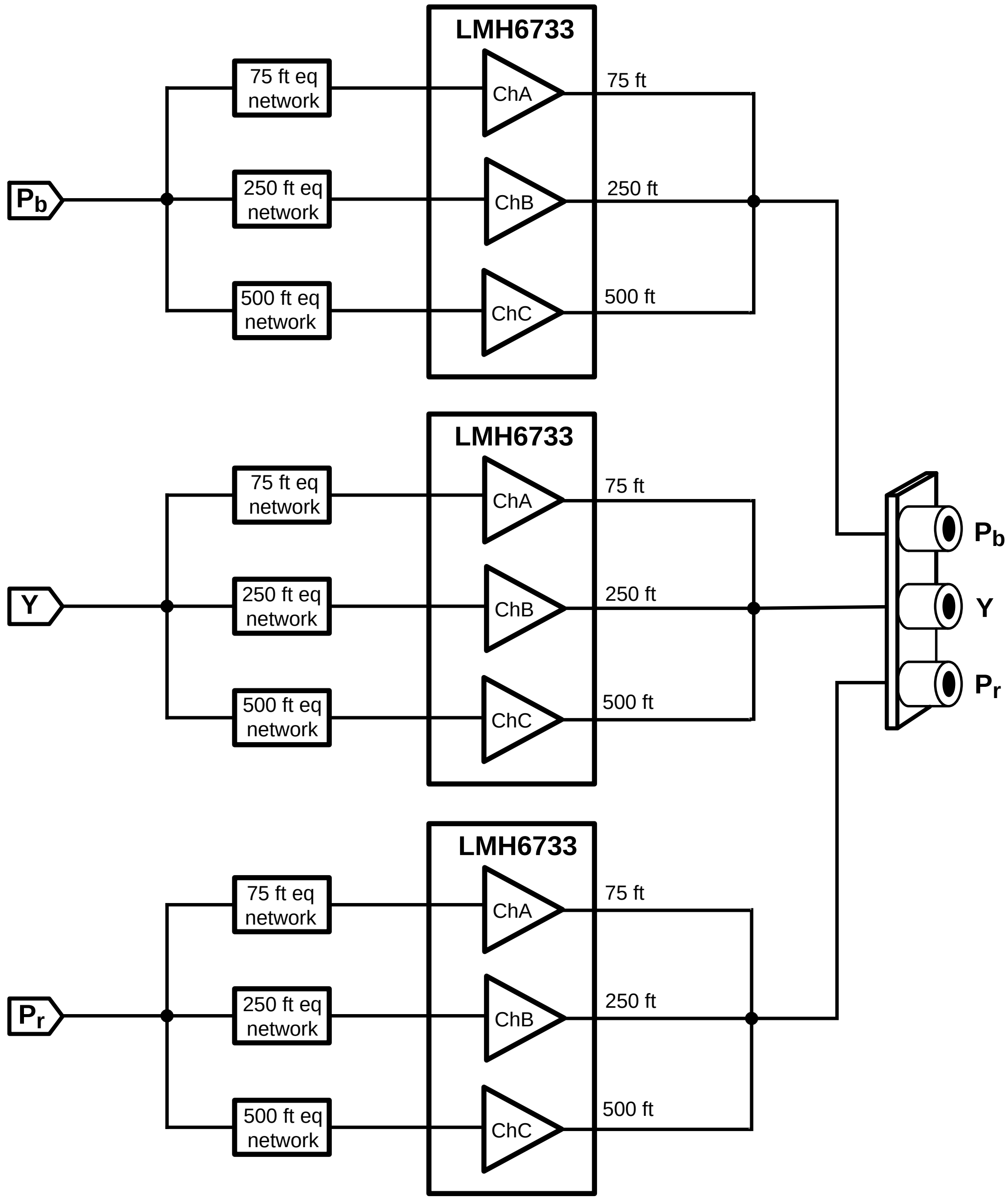


Figure 7. Entire Equalization Circuitry Block Diagram

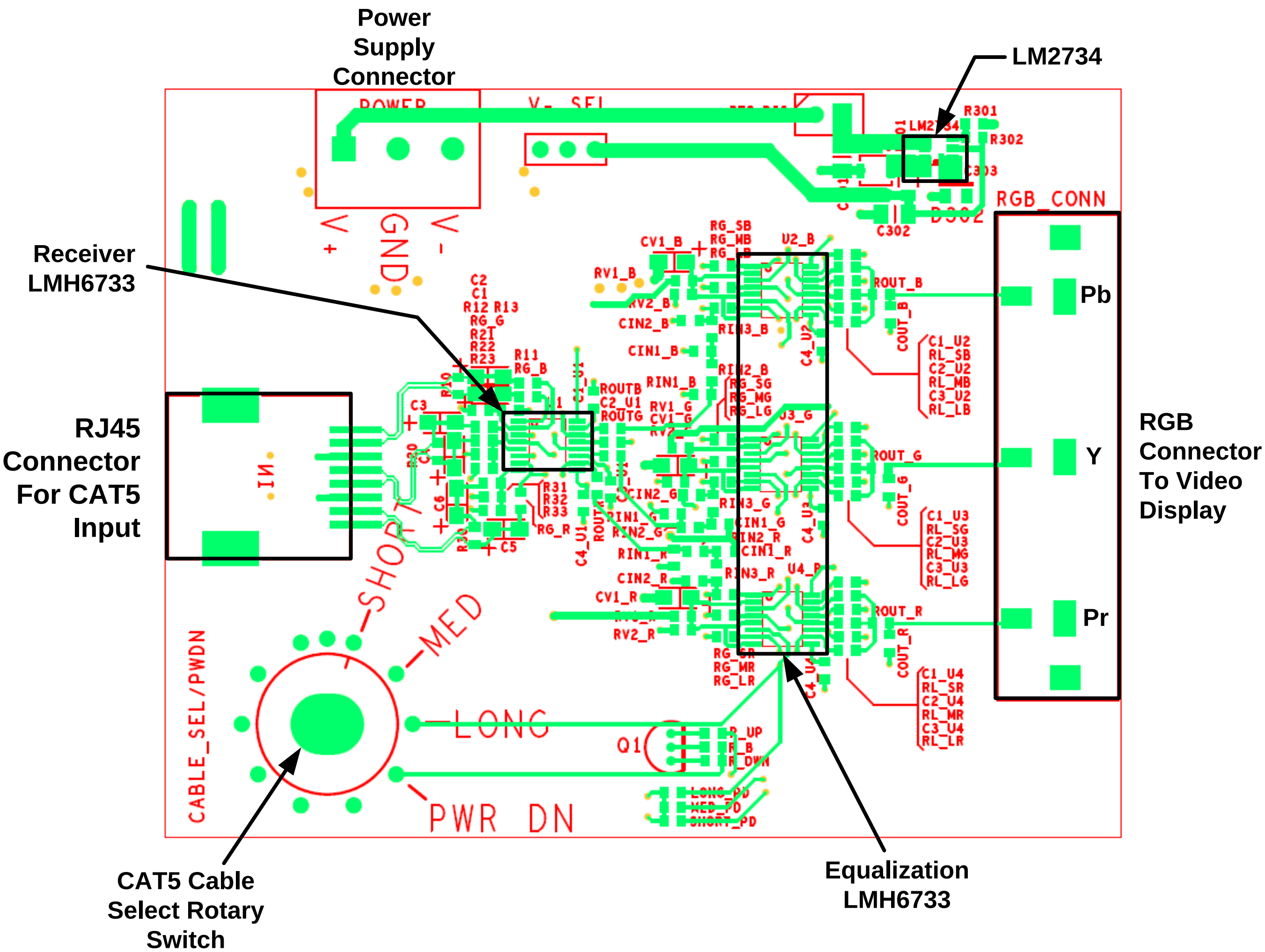


Figure 8. Receiver and Equalization Reference Board

Only one channel of equalization can be enabled by positioning the rotary switch to SHORT, MEDIUM, or LONG to select the desired length of CAT5 to equalize. Enabling of the channels is achieved by connection DISA, DISB, or DISC to +5 V. The other two channels are disabled by a 1 kΩ pull down resistor. For example, when SHORT is selected for a maximum cable length of 75 ft, channel A of all three LMH6733 equalization devices are enabled while channels B and C of all three devices are disabled. The output can be sent to a video monitoring device through the RCA connector with indicators green-Y, red-Pr, and blue-Pb. Table 2 shows the switch positions, CAT5 cable lengths, and associated amplifier channels.

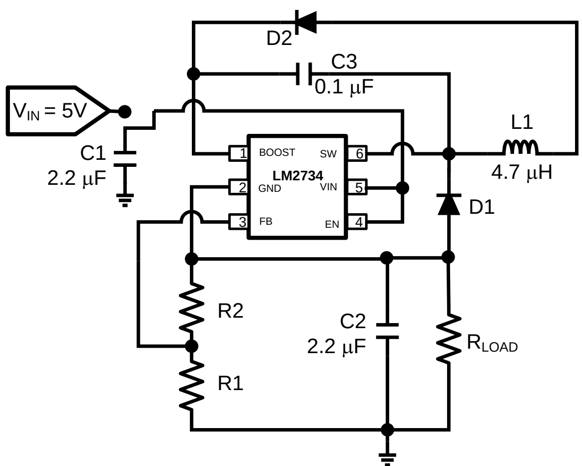
Table 2. Equalization Switch Table

Rotary Switch Position	Maximum CAT5 Cable Length	LMH6733 Channel Enabled
SHORT	75 ft	A
MEDIUM	250 ft	B
LONG	500 ft	C

Output resistors, R_O, are positioned to isolate the enabled channel from parasitic capacitance of the disabled channels. Each disabled channel may add up to 2 pF of capacitance to the enabled channel and may cause the circuit to oscillate. To achieve an overall cascaded gain of +2 V/V for the receiver and equalization amplifiers, the equalizer amplifier should have a gain of −1 V/V. However, due to the signal attentuation by the low-pass filters, R_O, and R_L the gain is increased slightly to −1.4 V/V, thus, making R_G = 383 Ω and R_F = 550 Ω

4 Power Supply and Signal Coupling

Both reference boards have the capability to be configured for either DC or AC coupled applications. If the desired signal path is to be DC-coupled, there are two power supply options. Option one is to connect a single +5 V power supply and have the LM2734 buck-boost regulator generate the −5 V supply voltage to power the LMH6733 amplifier(s) with jumpers on REG_DIS and V⁻_SEL set for regulator output REG_OUT. Figure 9 shows the LM2734 circuit and equations. From the equations, if R2 = 750 Ω and $|V_O|$ = 5 V, then R1 = 4 kΩ by calculation. The second option is to bypass the LM2734 regulator and directly power the board with +5 V and −5 V supplies using the three terminal power supply connector with a jumper on V⁻_SEL set for external negative supply EXT V⁻. The third option is to bypass both the LM2734 regulator and use a single +5 V power supply. For this option, modifications to the board have to be made to AC couple and appropriately bias the inputs of the LMH6733 device.



(1) $V_C = V_{BOOST} = (V_O + V_{D1}) - V_O$

(2) $i_{fd} = \dfrac{0.8}{R_2}$

(3) $V_O = i_{fb} \times (R_2 + R_1)$

Figure 9. LMH2734 Circuit and Equations for −5 V Supply Generation

4.1 Transmit Board Modifications for AC-Coupling

1. Cut traces on C1A, C1B, and C1C. Replace with 47 µF tantalum capacitors.
2. Add 1 kΩ resistors for R1A, R1B, R1C, R2A, R2B, and R2C.
3. Add 1.5 µF tantalum capacitors for C2A, C2B, and C2C.
4. Add 2 kΩ resistors for R3A, R3B, and R3C.
5. Add 766 Ω resistors for R4A, R4B, and R4C. Replace RGA, RGB, and RGC resistor value of 383 Ω with 766 Ω.

4.2 Receive and Equalization Board Modifications for AC-Coupling

1. Cut traces on C1-C6. Replace with 4.7 µF tantalum capacitors.
2. Add 200 Ω resistor for R13, R23, and R33. Replace 100 Ω resistors R12, R22, and R32 with 200 Ω.
3. Replace R, R, and R with 470 µF tantalum capacitors.

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