Construction project:

Optical link for stereo headphones

Here's the design for a two-channel optical link which allows you to enjoy high quality sound reproduction on your stereo headphones, without messy and constricting cables. The transmitter unit is easily connected to a TV, hifi amplifier or similar, while the receiver is very compact.

With the advent of personal "walkie" type AM/FM type receivers, cassette players and CD players, the benefits of modern, lightweight headphones as a quality sound reproducing medium have become obvious. Not only do they give you the "big sound" image at whatever volume you wish, but you don't have to burden everyone around you with your choice of entertainment. A truly personal listening pleasure.

You may wish to extend this means of listening to your lounge room or bedroom, so that you can enjoy your favourite TV show or record in the comfort of a lounge chair or bed.

Simple! Just plug the headphones into the TV or hifi, sit back and relax. But oh no! The cord's not long enough. No problem, add an extension; but here we go again. Everybody trips over it, the dog uses it as a bone. Grandma doesn't always see it and ends up with it around her legs, after ripping off both your ears . . .

Here's the answer. A personal headphone receiver with a safe, non-interfering infrared (IR) optical link back to a transmitter at the TV, hifi or whatever. Not only does it solve the problem of long cables, it gives you the ability to listen to your favourite program while the rest of the family enjoy theirs. It's also handy for grandpa who can't hear too well these days. He can set his personal IR headphone receiver to the volume level he likes, without blasting the rest of the family out of the room.

Incidentally the IR optical link described here has been developed in the R&D department of Dick Smith Electronics. Kits for the link will therefore be readily available from DSE's many stores and dealers throughout Australia and New Zealand. Please note, however that the design and PCB artwork are covered by copyright, and may not be reproduced commercially without permission from DSE.

It's used by simply plugging the transmitter into the hifi amplifier's tape out terminals, or the TV's earphone socket. Any similar sound source can be used. It is an extension of your listening pleasure, without the need for hard-wired cable links or the invasion of other family members' listening pleasure.

The range of the system is sufficient for greater than the average sized room. Any number of receivers can be used with the one transmitter; they are simply pointed towards it. The receivers will even work at short range with reflections off walls. The receiver is powered by a standard 9V battery, the transmitter from a 12V power supply or a 9V or 12V battery eliminator.

How it works

The mode of transmission for the IR carrier system is frequency modulation (FM). The transmitter circuit is based around two LM566 voltage controlled oscillators (VCO). The outputs from the VCO's are mixed and fed to an output stage to drive the IR LED's (LED1-8).

The frequency of each VCO is set by capacitors connected to pin 7 (C6, C13) and the resistor/potentiometer connected to pin 6. The right channel VCO (IC1) has components selected to set the centre operating frequency at 110kHz, while the left channel components around IC2 are selected for 256kHz operation. Each output is taken from pin 4, which delivers a triangular waveform. The following RC components act as a simple filter to shape the waveform closer to that of a sinewave.

The transmitter unit, housed in the same compact plastic case as the receiver.

The receiver unit, with typical lightweight headphones. It runs from a standard 9V battery.

Frequency modulation of each VCO is accomplished by feeding the incoming audio signal into pin 5, the voltage control input of the oscillator. This pin is commonly called the modulation input. The resistors R6 (R15) and R7 (R16) set the correct DC operating point for the IC. Capacitor C5 (C12) is added to prevent possible oscillation in the current source. Any change in the voltage at pin 5 will cause a corresponding change in the oscillator frequency. The greater the change of this voltage, the greater the deviation of frequency from the centre point.

The preceding stage to the VCO is a conventional transistor amplifier to provide the necessary signal level and a stable source to drive the modulation input. Control over varying signal source levels is provided by VR1. Even though this control may be loosely termed the volume control, it is in fact the frequency deviation control for the transmitter. Without this control, the incoming audio signal may be too high and cause over-deviation, producing distortion in the receiver. On the other hand, if this level is too low, the signal to noise ratio of the signal at the receiver would be unacceptable.

In order to improve the general signal to noise ratio of the system, the incoming audio signal is given pre-emphasis by adding a bypass capacitor, C4 (C11) to the emitter of the transistor.

After the two carriers are mixed via resistors R9 and R18, the resultant signal is AC coupled to the output stage (Q3, Q4). This stage operates in class A, to provide a linear transmission of the mixed FM signals, in order to keep the intermodulation products at a minimum. The output current into the parallel-series IR LED bank is limited by the 6.8 ohm emitter resistors R21.

To cater to varying power supply inputs, an adjustable voltage regulator setup using a 7805 is used. With a nominal input of 12 volts, the regulator output is set to 9V. For a 9 volt supply, the output is set to 7V. The power supply connected has to have a current capability of not less than 200mA.

To recover the audio signal from the FM carriers, a suitable detector circuit is required. In this case, LM565 phase locked loop (PLL) chips are used. The centre frequency is set by the capacitor C17 (C18) on pin 9 and the resistors VR1 (VR2) and R25 (R26) on pin 8. IC2 decodes the right channel 110kHz carrier, and IC3 the left hand 256kHz carrier.

The signals are fed into pin 3 of each LM565 from the pre-amplifier/filter stages. Resistors R19 and R24 provide the correct operational bias point for the input stages of both PLL's.

The IR signal arriving at the photodiodes PD1/PD2 can be at a very low level, and has to be amplified to meet the input requirements of the LM565s. Two photodiodes are used in parallel to give a wider acceptance angle to the incoming signal. They are wired in a reverse bias mode for this application and are seen by the first amplifier as a varying capacitive source.

A 4069UB CMOS inverter is used as the active element of the amplifier stages. Each inverter is configured in a near-linear amplification mode (for low level signals), with the output fed back to the input via a resistor. This sets the output voltage near half the rail potential present at pin 14. The gain of the amplifier is set by the combination of the feedback resistor divided by the input resistor. Although this mathematical figure is only true at low gain factors, a high value feedback resistor will still set the output bias point at around the centre rail value.

Two stages of gain are provided after the photodiodes (IC1a, IC1b) prior to the filter block. A combination band stop, band pass network separates the two frequencies from the incoming signal. Amplifier sections IC1c and IC1d raise the signal level out of the filter and pass the 110kHz carrier to PLL IC2. Sections IC1e and IC1f similarly amplify the 256kHz carrier for IC3.

The recovered audio signal from the PLLs also carries some residual carrier. The simple RC filters between the PLLs and the output stages suppress this. Deemphasis is also performed by these filters. The signal level is set by VR3 volume control before entering the LM386 output stage. These amplifiers are only low power and are ideally suited to 32-100 ohm headphone use, but they will also drive high efficiency speakers.

Construction

The receiver printed circuit board is designed to be mounted in a plastic hand held case with a transparent front window. This case also has provision for a 9V battery.

Although the PC board is densely populated, assembly is straightforward. Load all low profile resistors, links and capacitors first, then fit the preset horizontal pots, RF chokes and larger capacitors. Next fit the battery lead (red +), switch earphone socket and volume

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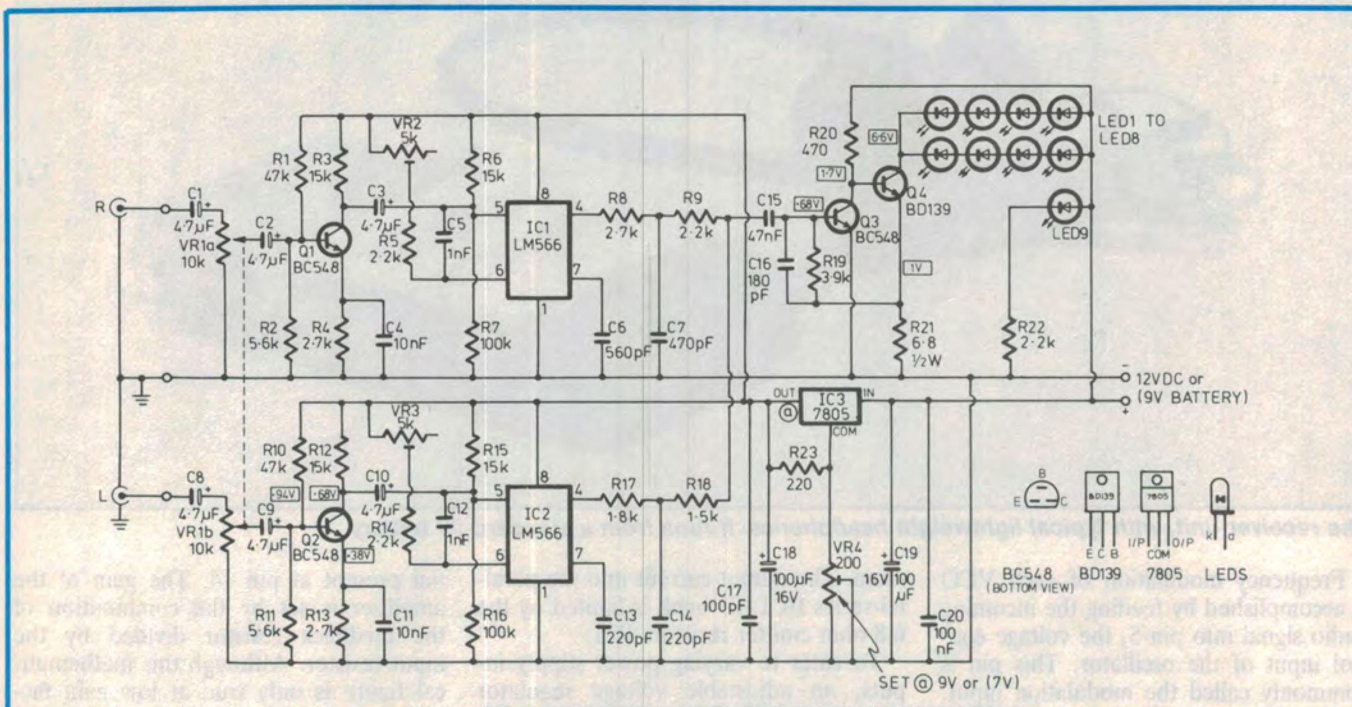
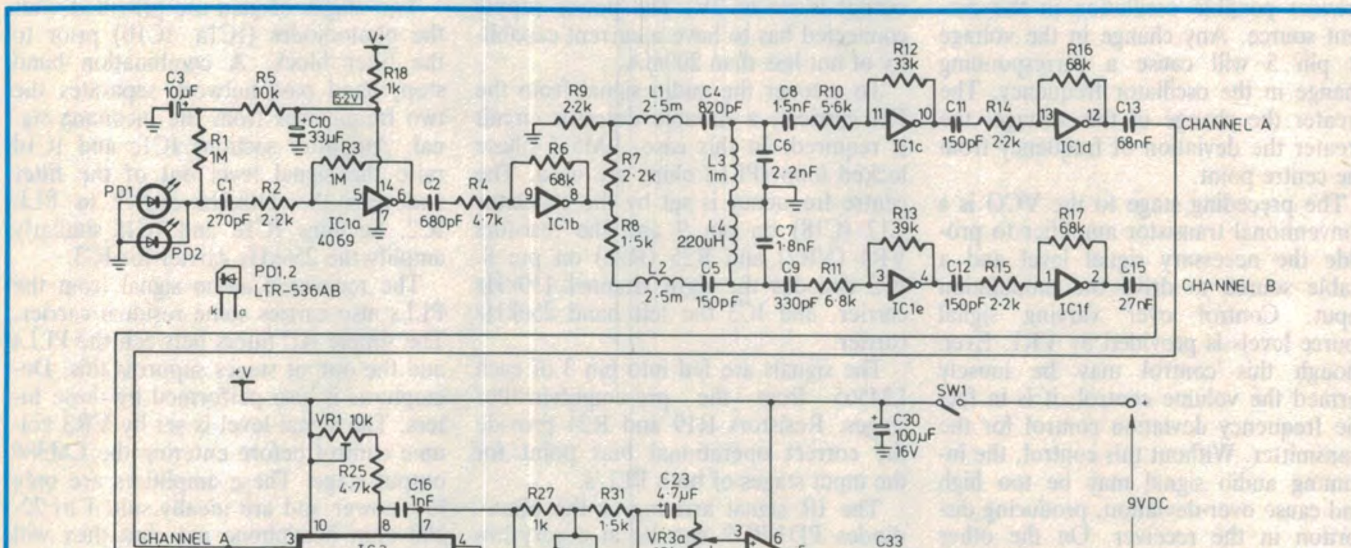
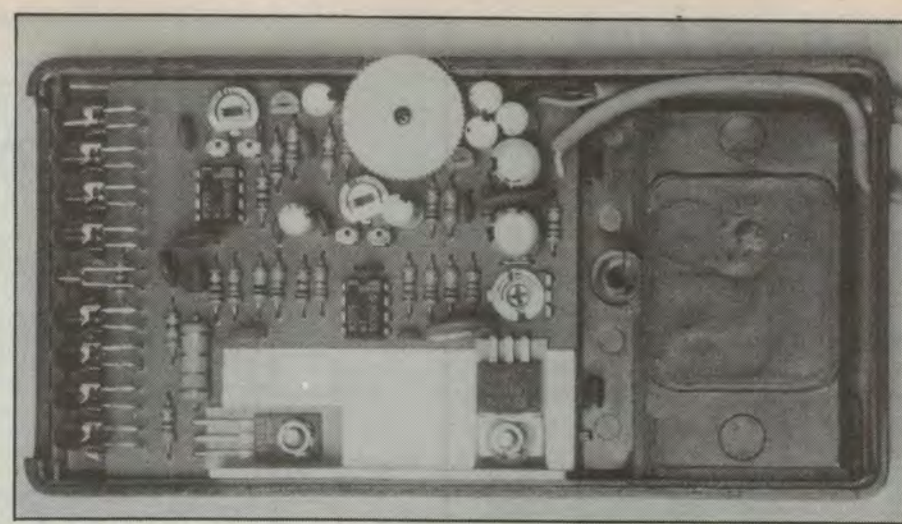


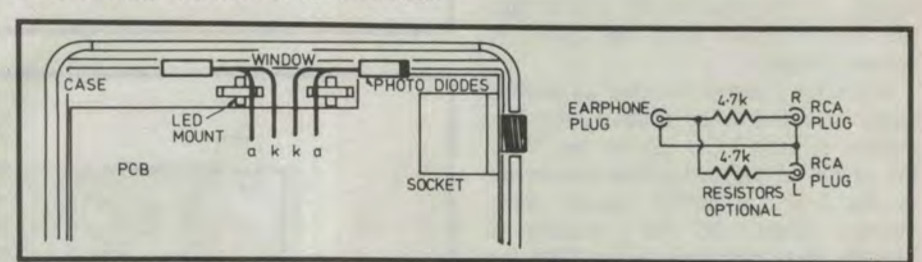
Circuit for the transmitter, which can be operated from either a 9V battery or a 12V DC plug pack supply.



The receiver circuit. At the heart are the two LM565 phase-locked loop chips, which demodulate the 100kHz and 256kHz carriers.



Inside the transmitter unit. Note the row of transmitting LEDs at the left, and the heatsink bracket for Q4 and IC3.



Above left: Details of the way the two photodiodes are mounted in the receiver. Right: A simple adaptor to drive the transmitter from a mono signal.

control. Be careful fitting this control — do not insert it with brute force. Gently push it down to lie flat on the PCB surface. Lastly fit the photodiodes with polarity as shown, and solder at near lead length. These have to be bent when inserted into the case.

For the PCB to sit into the correct position inside the receiver case, the centre peg and the two PCB fingers nearer the front have to be cut off (but not the two at the rear). Use a sharp knife blade or a small pair of side cutters to remove these points.

Now using the completed PCB as a guide, lightly mark the RH edge of the case half where the switch, volume control thumbwheel and earphone socket fall. The final board position is where the front edge is right up to the LED mount brace shoulders, and slightly under the PCB fingers at the rear. Now carefully file out the switch ferrule hole with a small round file. The final hole depth will allow the ferrule to fit snugly into position, so that the PCB fits under the finger and on top of the mount adjacent to it.

Next neatly file out the flat slot for the thumbwheel, and the half round hole for the earphone socket. Carry out this whole procedure carefully and patiently, bit by bit with a trial fit after each cut. The end result should be a snug fit with the board virtually snapping into place.

Now bend the two photodiodes around the LED posts, so that the sensitive surface of each faces towards the front, close to the position of the plastic window. Now bring the top case half to match the bottom by aligning the rear first. Mark this half at the points where the switch, wheel and socket meet. Again carefully file out the area required, with fitting trials at regular intervals. Fit the window into the slot provided.

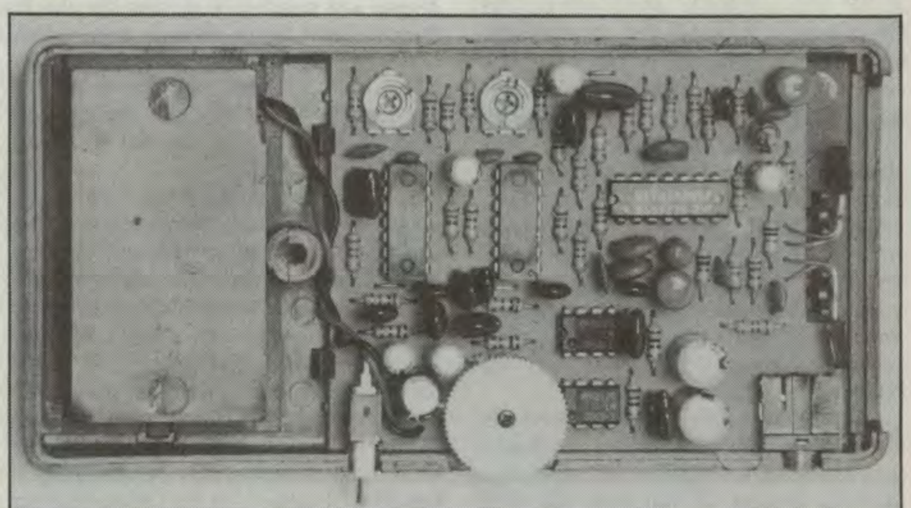
Stick the screen printed aluminium panel to the case with a small amount of contact adhesive, and feed the battery lead into the battery compartment.

The construction of the transmitter is similar to the receiver. Note that transistor Q1, is under the thumbwheel and has to be pushed right into the board to clear the bottom surface. The heatsink is aligned with the edge of the board and the BD139 transistor and the regulator are fitted with insulators. The 7805 regulator also has a nylon insulator fitted to the screw under the nut and washer. Both components have the legs bent at right angles to align with the holes in the PCB, They are secured with M3 x 10mm screws, nuts and washers.

The leads of the IR LEDs are bent at right angles, so that they point out through the window area. Note the polarity before bending. The red LED polarity is different from the others with respect to the bend.

As with the receiver, the transmitter case must be modified by cutting of the centre peg and the two PC fingers. You'll also have to file out the case halves to accommodate the thumbwheel, and drill two holes of suitable size in the bottom case half to allow access of the two cables for the power and audio signals.

The larger two core audio cable holes can be drilled between the battery compartment and the RH edge. The smaller power supply cable hole can be drilled in behind the battery compartment, next to the audio cable hold. Feed the cables through and terminate onto the board. Make the red wire of the audio cable the right hand channel. The centre wire of the power cable is the posi-



Inside the receiver unit. The two preset pots are VR1 and VR2 used to set the PLL centre frequencies for best results.

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tive lead. Fit connectors to these cables as you require.

Fit the screened aluminium front panel to the transmitter case with a small amount of contact adhesive.

Setting up

After a complete check of the components placement, orientation and soldered joints, the transmitter can be connected to a power supply. Ideally, a 12 volt @ 200mA supply is suggested, although a 9 volt @ 200mA will operate the system quite well.

Switch on and measure the voltage at the output of the regulator IC3. Adjust VR4 so that this value reads 9V with a 12V supply; or if you are using a 9V supply, set the value to 7V. Check that the current drawn from the supply is around 200mA.

If you have access to either an oscilloscope or a frequency counter, the frequency of each VCO can be set. With the probe of the instrument connected to pin 3 of LM566/IC1 (square wave output), adjust VR2 for a reading of 110kHz (9us). Similarly adjust VR3 for a reading of 256kHz (3.9us) at pin 3 of IC2.

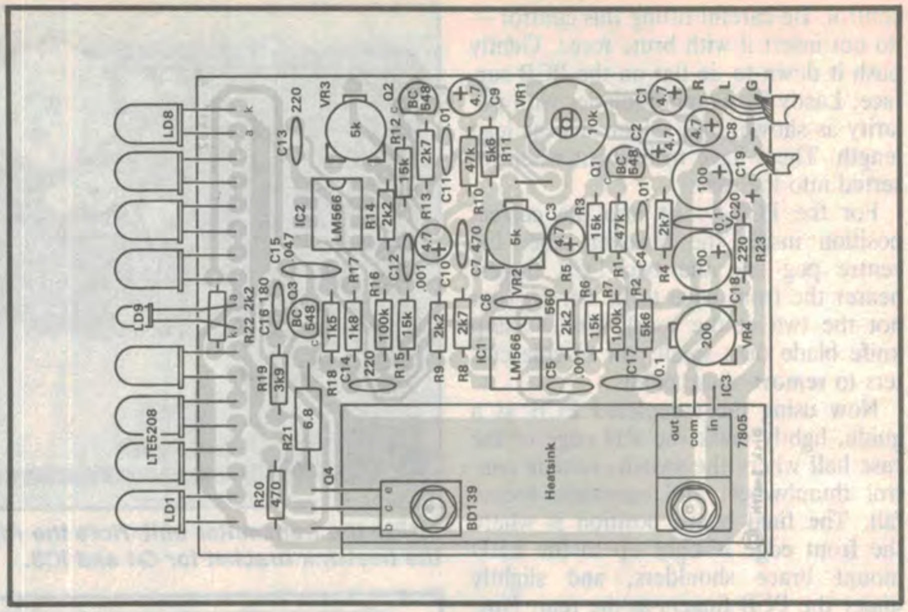
If you haven't these instruments, see the section below for an alternative tuning procedure.

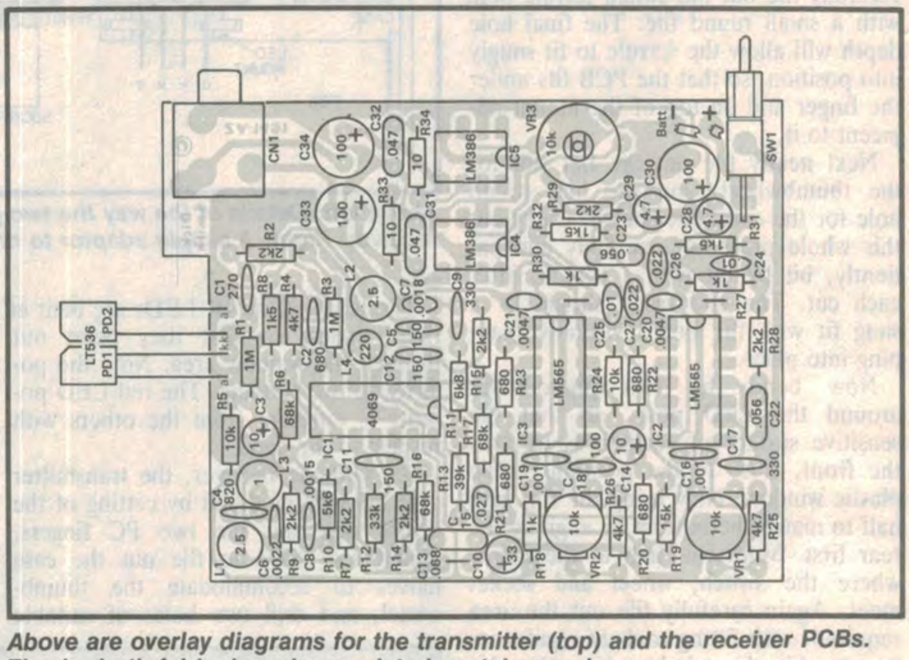
To set up the receiver, again check all component placement and soldering. Connect a 9V battery and headphones. On switch on, with the transmitter off, you should hear noise that varies with direction dependant on the light source that the photodiodes face. The current drawn by the receiver should be around 25mA @ 9V.

Plug the two audio leads of the transmitter into a suitable signal source. An FM tuner is a good test component. Power up the transmitter but leave the volume control set to minimum at this stage. You should hear some change in level of noise at the receiver as the photodiodes are directed towards the transmitter.

With a small screwdriver, adjust each preset pot on the receiver VCOs for minimum noise. Move further away from the transmitter and readjust the controls. Repeat this process so that maximum range and sensitivity is achieved.

If you have previously adjusted the transmitter with a frequency counter, then this final setting should come close to being correct. If you hear low level whistles coming from one channel, slightly adjust the high frequency pot





Above are overlay diagrams for the transmitter (top) and the receiver PCBs. They're both fairly densely populated, so take care!

VR3 on the transmitter board to null out this noise. It may be necessary to readjust VR2 on the receiver to match this change.

If you haven't access to test equipment to set the two frequencies of the transmitter channels, we found that the mechanical position of the wiper of each preset pot in the transmitter was slightly off centre between 11 and 12 o'clock. Use this as a starting point and adjust the receiver to give minimum noise with these settings. Trail and error adjustments should find good results. Some small readjustments may be necessary if you find "birdies", or bad distortion occurring at low levels of program material.

With the basic tuning done, turn up the volume control on the transmitter. The receiver should burst into life with the program signal. This control is set to a point just under where the sound starts to distort on high level passages. This overload point is where the deviation of the FM carrier, modulated by the incoming audio signal, is beyond the limits of the system. This overload point will tend to become more noticeable as the distance between the transmitter and receiver is increased.

Optical filters

The cases used in the DSE kit for this project have a red optical window built into the front. On the prototype system, we found that interference from internal artificial light was minimal provided the receiver was not a long way from the transmitter or far off direction.

Background buzz from fluroescent lights can be heard in weak signal conditions if the light source is in the receiver photodiode acceptance angle. We experimented with linear polarized filter material with the Yz axes crossed. Used as a window, this gave an improvement to the signal to noise ratio but we felt that the added cost was not justified for an extreme condition. For reference, the material used was Polaroid HN32 or HN22. Unfortunately, this material is only available from Polaroid Australia in 300mm x 420mm x 0.7mm sheets.

The receiver has a directional characteristic because of the position of the diodes inside the case. If these diodes were placed outside the case, in front of the window position, a more omni-directional receiving pattern could be achieved. The diodes could be placed in a back to back arrangement to obtain a wider field of view. However, this creates a problem of housing and the exclusion of all but IR light.

Constructors may wish to experiment with this idea if the directional characteristic of the receiver is a problem in use.

PARTS LIST

RECEIVER

Semiconductors

1 4069uB
2 LM565 PLL
2 LM386 audio amps
2 LT586AB photodiode

Capacitors

1 270pF ceramic
1 680pF ceramic
2 10uF/25V RB electro
1 820pF ceramic
3 150pF ceramic
1 2.2nF ceramic
1 1.8nF metallised polyester
1 1.5nF metallised polyester
2 330pF ceramic
1 33uF/10V RB electro
1 68nF metallised polyester
1 2.7nF metallised polyester
2 1nF ceramic
1 100pF ceramic
1 4.7nF ceramic
2 56nF ceramic
2 10nF ceramic
2 22nF ceramic
2 4.7uF/25V RB electro
3 100uF/16V RB electro
2 47nF metallised polyester

Resistors (all 0.25W, 5%)

2 1M, 7 x 2.2k, 3 x 4.7k, 2 x 10k 3 x 68k, 3 x 1.5k, 1 x 5.6k, 1 x 6.8k, 1 x 33k, 1 x 39k, 3 x 1k, 1 x 15k, 4 x 680Ω, 2 x 10Ω
2 10k 10mm horizontal trimpot
1 10k log pot

Inductors

2 2.5mH RFC
1 1mH RFC
1 220uH RFC

TRANSMITTER

Semiconductors

2 LM566 VCO
1 7805 regulator
3 BC548 transistor
1 BD139 transistor
8 LTR5208 IR LED
1 3mm RED LED

Capacitors

3 4.7uF/25V RB electro
4 10nF ceramic
2 1nF ceramic
1 560pF ceramic
1 470pF ceramic
3 4.7uF/25V 28 electro
2 220pF ceramic
1 47nF ceramic
1 180pF ceramic
2 100uF/16V RB electro

Resistors (0.25W, 5%)

1 x 47k, 1 x 5.6k, 1 x 15k, 3 x 2.7k, 4 x 2.2k, 3 x 15k, 2 x 100k, 1 x 47k, 1 x 5.6k, 1 x 1.8k, 1 x 1.5k, 1 x 3.9k, 1 x 470Ω, 1 x 270Ω, 1 x 220Ω
1 x 6.8Ω 1/2W
1 10k log dual volume control
2 5k 10mm horizontal trimpot
1 200Ω 10mm horizontal trimpot

Miscellaneous

1 case c/w screen and window
1 screened front panel to suit case
1 PCB
1 SPDT PC mount toggle switch
1 3.5mm stereo PCB mount socket
2 TO-220 mica insulators
1 TO-220 nylon insulator
2 M3 x 10mm screws
2 M3 hex nuts
2 M3 flat washers
1 56mm heatsink
1 1m 2 core round shielded cable
1 1m 1 core shielded cable
1 3.5mm stereo plug
2 RCA plugs
1 3.5mm socket
1 9V battery snap