Optical Wireless Receiver for IrDA Links

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Summary

The aim of this 3rd year project was to implement a unidirectional optical wireless data link over which useful information could be sent. The project was particularly concerned with the design of the receiver circuit to minimise noise and maximise sensitivity and possible bandwidth. To increase the effectiveness of the receiver it used the ‘optical antenna’, a novel optical concentrator patented at Warwick University. The link was designed with an LED transmitter and a pin photodiode based receiver. The receiver used a single stage high impedance JFET amplifier connected to a JFET input operational amplifier. The link was tested by transmitting various sine waves and baseband audio over a distance of up to 1 meter. A reasonable signal level was achieved at frequencies up to 50kHz and recognisable audio could be transmitted, although this was partially masked by lower frequency noise. Although a potentially operational link was produced the results were not ideal and hence improvements, additions and modifications to the system were considered.

The most significant conclusion was the overall simplicity and low cost of producing an optical wireless link compared to its radio frequency counterparts and the potential this offers in the present and future.

Contents

1. Project Objectives

This project is concerned with the implementation of an optical wireless receiver using the new Optical Antenna patented at Warwick. The project will act as a demonstration of the benefits of the antenna. The project will include the design and building of a working transmitter and receiver. The result should be a working link over which useful information may be sent. The design will concentrate on maximising the performance of the receiver. A simple understanding of the optical system is needed but complex analysis is not required.

2. System Technical Requirements

The system requirements are declared as follows:

- The project should result in an optical wireless data link over which useful information can be sent.
- The receiver should in theory be able to operate as part of an IrDA data link.
- The system will use the optical antenna in the receiver unit.
- The link should be capable of operating over a distance of up to at least 1 meter.
- The link is to be as low noise as possible with minimum distortion.
- To test the system, it should be able to transmit high quality baseband audio with the input and output at a standard hi-fi line voltage.
- To ensure the audio is of high enough quality a minimum of 44kHz bandwidth is required.

3. Introduction to Optical Wireless and IrDA

Optical wireless has long been thought about for communications between devices in addition to the more publicised radio wireless systems. The IrDA is an organisation that creates and promotes low cost infrared data interconnection standards that support a walk-up, point-to-point user model. Currently many mobile phones, PDAs and laptop have IrDA transceivers built in. These do however have a short range and correct alignment between devices is crucial.

Optical wireless has many advantages over wired or radio communication techniques. Many advantages of wireless are obvious, portability, tidiness and universal connectability are among a few. Optical wireless excels against radio based systems due to its increased security, potential for extremely large bandwidths and low cost. Radio based networks are know for potential security problems where someone with a laptop can connect to a private network from outside the building, so called ‘war driving’. This is not a problem where infrared is concerned as the signals are confined to the space they were intended for.

A simple and low cost led and diode based receiver can be used for infrared communications whereas complex and costly transmitter and receiving devices are required for radio communications. Radio spectrum is very expensive to purchase with limited bandwidth available in public allocations, whereas infrared provides naturally unregulated, free bandwidth. Some problems, however do arise. Even diffuse infrared systems require a reasonably open area with no obstructions such as walls so it is potentially more useful in a space such as an open plan office rather than an entire private house. The limited range of infrared would require a transmitter in each room. Similarly an infrared device could not, for instance, be carried in a pocket and communicate with other devices, as is possible with a radio based system.

Although non-LOS (line of sight) infrared systems are possible indoors due to the high reflectability of infrared radiation from walls and other common surfaces this project concentrates on a LOS data link suitable for digital data. In the future we are likely to offices with wireless infrared LANs illuminated with a central ceiling mounted transceiver making a wireless microcell within the high speed company intranet. Ultimately it should be possible to walk in to an office or home and access instant data and communication services via portable or non-portable devices connected to a secure wireless infrared network.

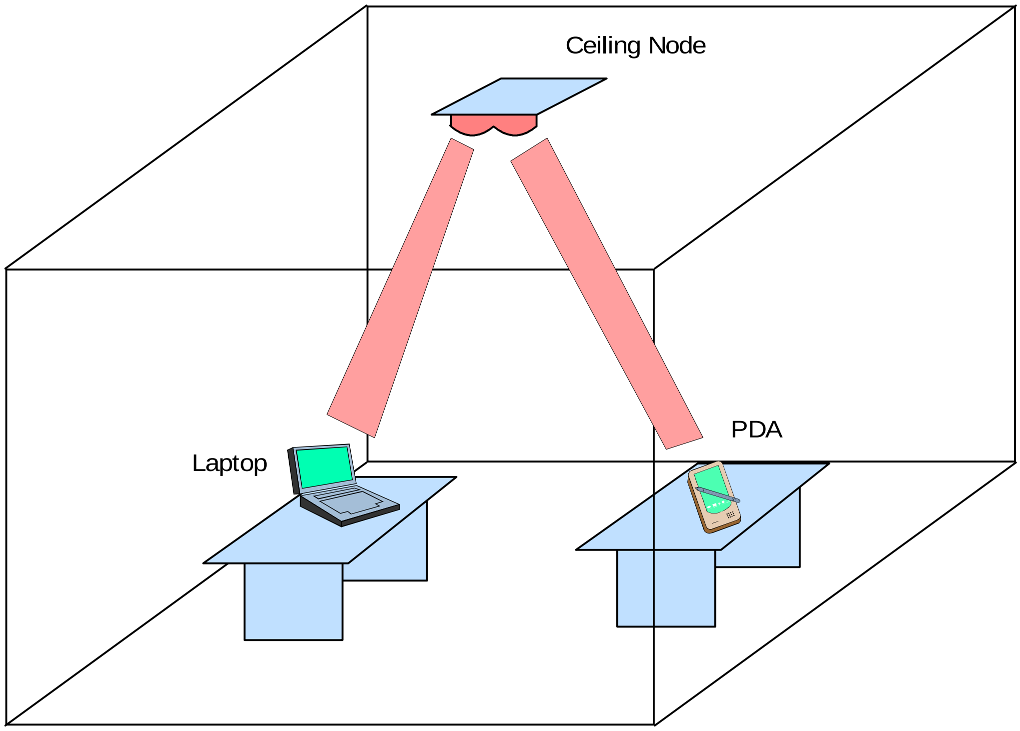

Figure 1 Optical Wireless LAN (Microcell)

It is likely that infrared receivers will not be able to replace radio receivers but they can coexist, offering different advantages and hence services[1].

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[1] Section 1.1 (page 2), Barry, John R., Wireless infrared communications, Kluwer Academic Publishers, 1994.

4. Design Process

The wireless infrared link to be investigated will be a line of sight (LOS) link for relatively short distances as encountered between portable electronic devices in an office/portable office environment, typically a few meters maximum. The IrDA standard is concerned with transmission distances of less than a meter[2]. Examples of a use for such a communication link include mobile phones, PDAs, laptops, and other portable devices. A fairly wide-angle irradiance field is preferable for the transmitter. This would to present the user with a simpler system where alignment problems are reduced, resulting in a more reliable link performance. This is one area where application of the optical antenna is particularly useful since it is able to collect light from a wide range of angles.

4.1 General Design Considerations

A simple transmitter, capable of transmitting baseband modulated audio is required. This should have a bandwidth of at least 44kHz and minimal distortion. A higher specification transmitter is not required but could be used to further test the receiver limitations.

Typical components of an optical receiver system include[3]:

- Optical detector: convert modulated light into electronic signal
- Preamplifier: amplify weak electrical signal (μV to few mV)
- Equaliser: recover bandwidth lost in preamplifier
- Post-Amplifier: further amplifies signal (mV to typically a few volts)
- AGC (Automatic Gain Control): Used to normalise the signal by removing variations in signal level caused by variable attenuation in the physical path. This provides a standard signal level for detection. (Typically included in the post amplifier)
- Filter: remove unwanted frequency components

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[2] http://www.irda.org/standards/standards.asp

[3] David A. Johnson, *Handbook of Optical Through the Air Communications*, http://www.imagineeringezine.com/ttaoc-pdf/OTTAC-Handbook.PDF (Receiver Section)

- Clock recovery: recover clock sent on optical signal
- Decision circuit: sample signal and recover data

A basic infrared unidirectional data link receiver system block diagram is shown below:

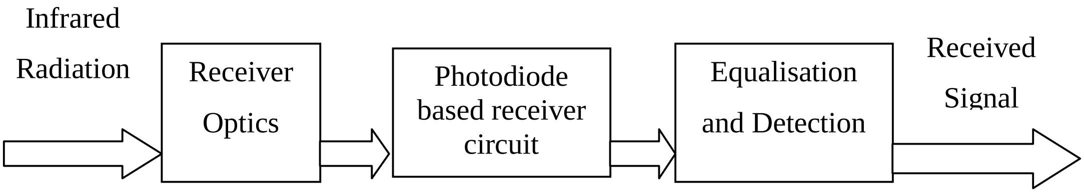

Figure 2 - General Receiver Block Diagram

The receiver optics is the system of optical devices that collect, concentrate and filter the infrared radiation before it strikes the photoelectric detector. In this project this consists of the optical antenna, an optical concentrator, bonded to an optical filter, in turn bonded to the detector, the photodiode. The optical antenna gathers light from multiple directions and concentrates it on one point, the detector. It is designed to collect light from a wide range of angles and concentrate it at a small angle of incidence onto the detector hence increasing sensitivity. The optical filters are designed as a narrow bandpass filter to allow only the required wavelengths of the infrared source (approximately 980nm in the case of this project) to reach the detector, blocking the majority of the unwanted background radiation (visible light etc.) which can swamp the detector. An in depth explanation of the processes involved in this physical layer is not required for this project.

The receiver circuit design is difficult due to the relatively high capacitances of photodiodes, and the high intensity background radiation. The entire system depends on the ability of the preamplifier circuit to amplify the detected signal over the desired bandwidth without adding undue noise[4].

The wireless infrared receiver design is fairly similar to that of optical fiber receivers with a few differences.

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[4] Section 3.1 (page 49), Barry, John R., Wireless infrared communications, Kluwer Academic Publishers, 1994.

Infrared wireless systems have a big disadvantage over optical fiber systems in that a considerable amount of the noise on the received signal comes from the background radiation from the operating environment. Even with optical filtering and matched led/photodiodes this is large compared to the received signal.

Larger area photodiodes required to collect enough light for a sufficiently strong signal mean higher photodiode capacitances and hence a more limited maximum bandwidth. The optical antenna improves this situation by concentrating light from a larger area to a small point, thereby reducing the size of photodiode required and allowing transmission over a greater distance.

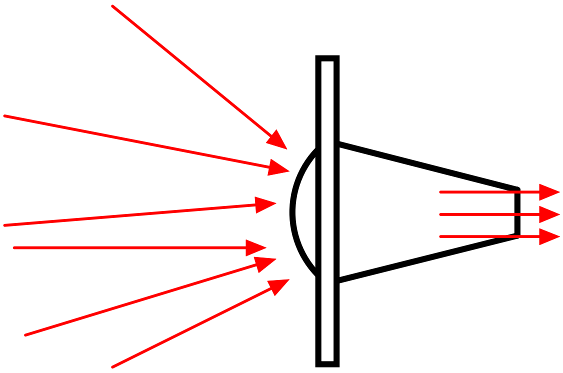

Figure 3 Optical Antenna

4.2 Photodiode Selection

Photodiodes generate a small current that is proportional to the level of illumination. The diode response is very linear and can be used as a measure of absolute light levels. The open circuit forward voltage drop across the photodiode varies logarithmically with light level, but because of its large temperature coefficient, the diode voltage is seldom used as an accurate measure of light intensity. Photodiodes may either be operated with zero bias (photovoltaic) or reverse bias (photoconductive). The most precise linear operation is obtained in the photovoltaic mode, while higher switching speeds are achieved when the diode is operated in the photoconductive mode. Under these reverse bias conditions, a small amount of current called dark current will flow even when there is no illumination. In communication systems the reverse bias is usually used. The two types of photodiode commonly used in optical communication systems are the PIN photodiode and the avalanche photodiode.

The receiver will be based on a PIN photodiode as Barry[5] proves the alternative component, the avalanche photodiode, is unsuitable due to the amplification by the APD of the large amounts of background radiation found in an optical wireless system.

The name, PIN photodiode, indicates that the device is made from p and n doped semiconductor (in most cases silicon) layers with a middle intrinsic (insulating) layer.

A standard silicon PIN photodiode has a peak response at a wavelength of around 890nm, this response falls off sharply beyond 1000 nanometers, but has a more gradual slope toward the shorter wavelengths, including the entire visible portion of the spectrum. It is this response curve that means a narrowband optical filter should be used to prevent unwanted radiation from entering the detector. Other important factors to consider when selecting a photodiode are the rise and fall time and the junction capacitance. Both will limit the bandwidth of a communication system. In order to minimise the effect of photodiode capacitance a diode with a small area is required. The output point of the optical antenna has a small diameter allowing photodiodes with small areas to be used. The photodiode selected is the BPX65 (RS Cat no 304-346) This has a window diameter of 3.9mm with an active area of 1mm^2, making it suitable for connection to the optical antenna. With a rise time of a few nanoseconds and a low junction capacitance is of a considerably higher specification than required for this project, being designed for high speed optical fiber applications. The data sheet is included in Appendix A.

4.3 Emitter LED Selection

The emitter LED must be matched to the peak response of the photodetector. In this case a silicon photodiode is used with a peak response in the infrared spectrum at 850-890nm. The LED must be of a high enough power to ensure sufficient optical power is incident on the receiver. The emitter angle must be suitable for the application, giving a reasonable level of dispersion without diffusing the optical output too much and wasting the optical power. In this application a relatively narrow irradiance

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[5] Source: Section 3.7.2 (page 69), Barry, John R., Wireless infrared communications, Kluwer Academic Publishers, 1994.

pattern is preferable, since it may be assumed that the transmitter will be aligned fairly accurately with the receiver. IrDA specifications allow for an irradiance pattern of 15-30°. The rise time and fall time of the emitter should be low enough to provide the highest possible potential bandwidth. It is preferable that the bandwidth of the receiver be tested above the minimum of about 44kHz necessary for the transmission of a high quality audio signal.

Suitable high-power infrared emitters (LEDs) can be produced using GaAs or GaAlAs semiconductors. These emitters can be produced with a output wavelength of around 890nm, matched to silicon's peak response.

The HIRL5015 and HIRL5010 GaAlAs Emitters were both considered. These had very similar specifications, but the beam angles were ±30° and ±15° respectively. The HIRL5015 was chosen since it has a wider irradiance pattern. It was decided that the irradiance pattern for the HIRL5010 was too restricted and would require too accurate alignment of the transmitter and receiver. The data sheet for the HIRL5015 is included in Appendix A.

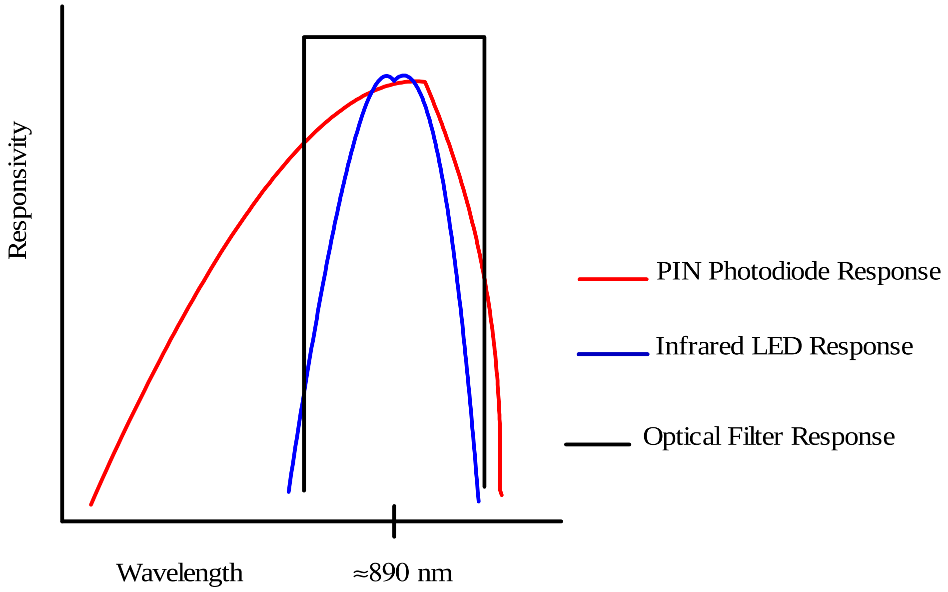

Figure 4 Photodiode, LED, and Optical Filter Responses

5. Transmitter Circuit Design

The current in the LED is linearly related to its optical power output. Varying the current in the LED will therefore vary the optical power output as shown in the figure below:

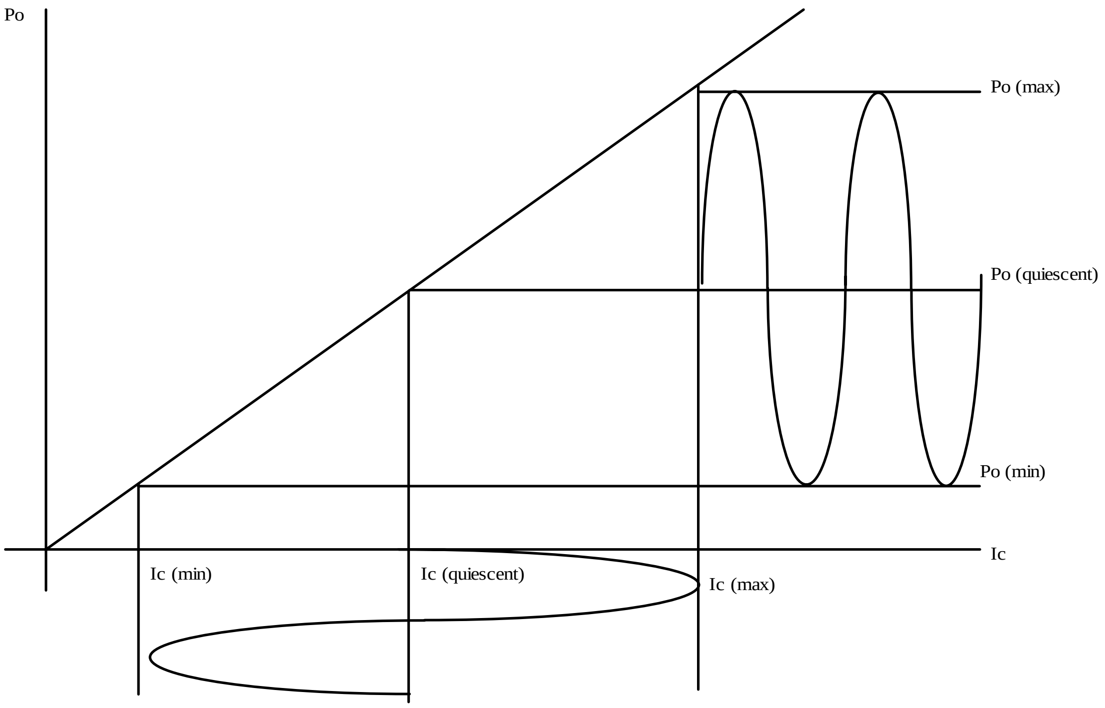

Figure 5 - LED current/optical power characteristic

The transmitter is therefore required to take an input voltage and use this to directly modulate the current in the LED. This simplest way of achieving this is to use a BJT (Bipolar Junction Transistor), noting the following relationship:

$$Ic \approx I_E \approx \left(\frac{V_B - V_{BE}}{R_E} \right)$$

The layout of such a circuit is shown in the figure below. The required input voltage will need to be set externally from this arrangement so as to operate the LED through its full range.

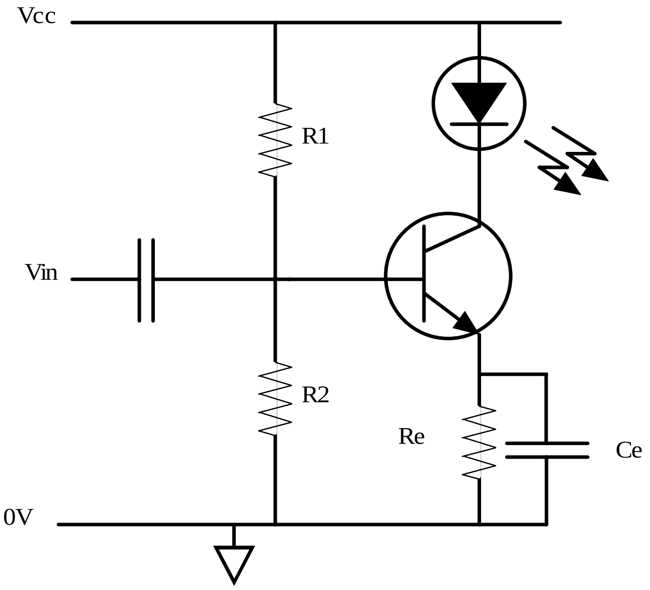

Figure 6 Transmitter Layout

The bias is required to be set so the LED is always on and the operating point allows for the full range of the LED. The circuit should be able to drive a current of up to 100mA (peak) into the LED. The operating point is chosen to give a quiescent current of 60mA. Therefore the maximum input voltage level should modulate the LED current between 20-100mA. This ensures optical power is still at a reasonable level at the ‘lowest’ input voltage. Re is chosen so about 25% of the input voltage is dropped across it for stability. With a supply voltage of 12V a value of 47Ω is chosen. From the equation above and using V_{BE} as 0.7V and a $I_{C\ (quiescent)}$ as 60mA V_B can be calculated as 3.7V. This is set using R_1 at 2.2kΩ and R_2 at 1kΩ, giving and input impedance of just below 700Ω. The completed circuit is shown below using a 2N2222 NPN bipolar junction transistor (BJT):

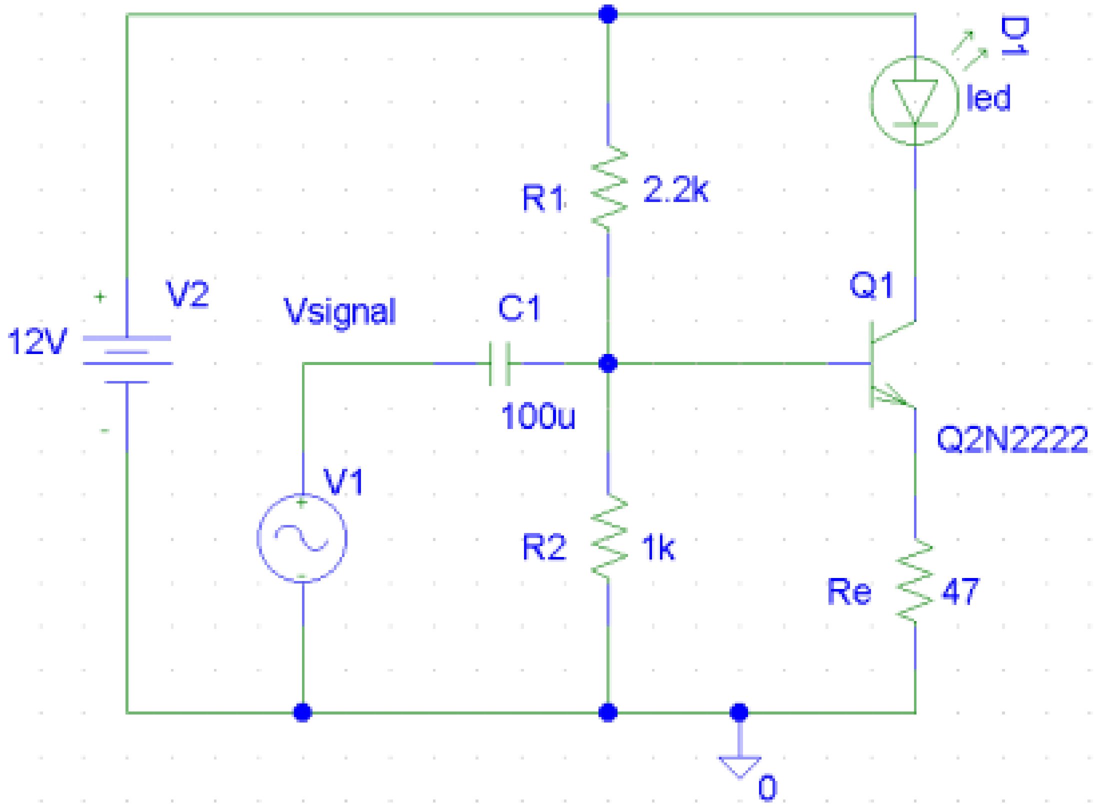

Figure 7 Transmitter Design

The required input signal level can now be calculated. At $V_{in\ (peak)}$ I_c should be 100mA. This gives the required V_B at approximately 5.7V giving a peak input voltage of ±2V. Since a relatively high current of 100mA is being used it is important that the transistor and its packaging can handle this current and dissipate the power. According to the data sheet[6] the 2N2222 is "designed for high speed switching application at collector current up to 500mA" the maximum rated collector current is given as 800mA.

This circuit will therefore modulate an LED from an ac coupled signal with a maximum voltage of 2V. It is therefore possible to directly connect this transmitter to an audio line voltage to test the receiver with audio. The input voltage and output waveform PSPICE simulations are shown in figure 8. A diode model with the required voltage drop of 1.5V is used (measured value). An input sinusoidal voltage of 2V is used. The simulations confirm the design should function as predicted.

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[6] 2N2222 Data Sheet See Appendix A

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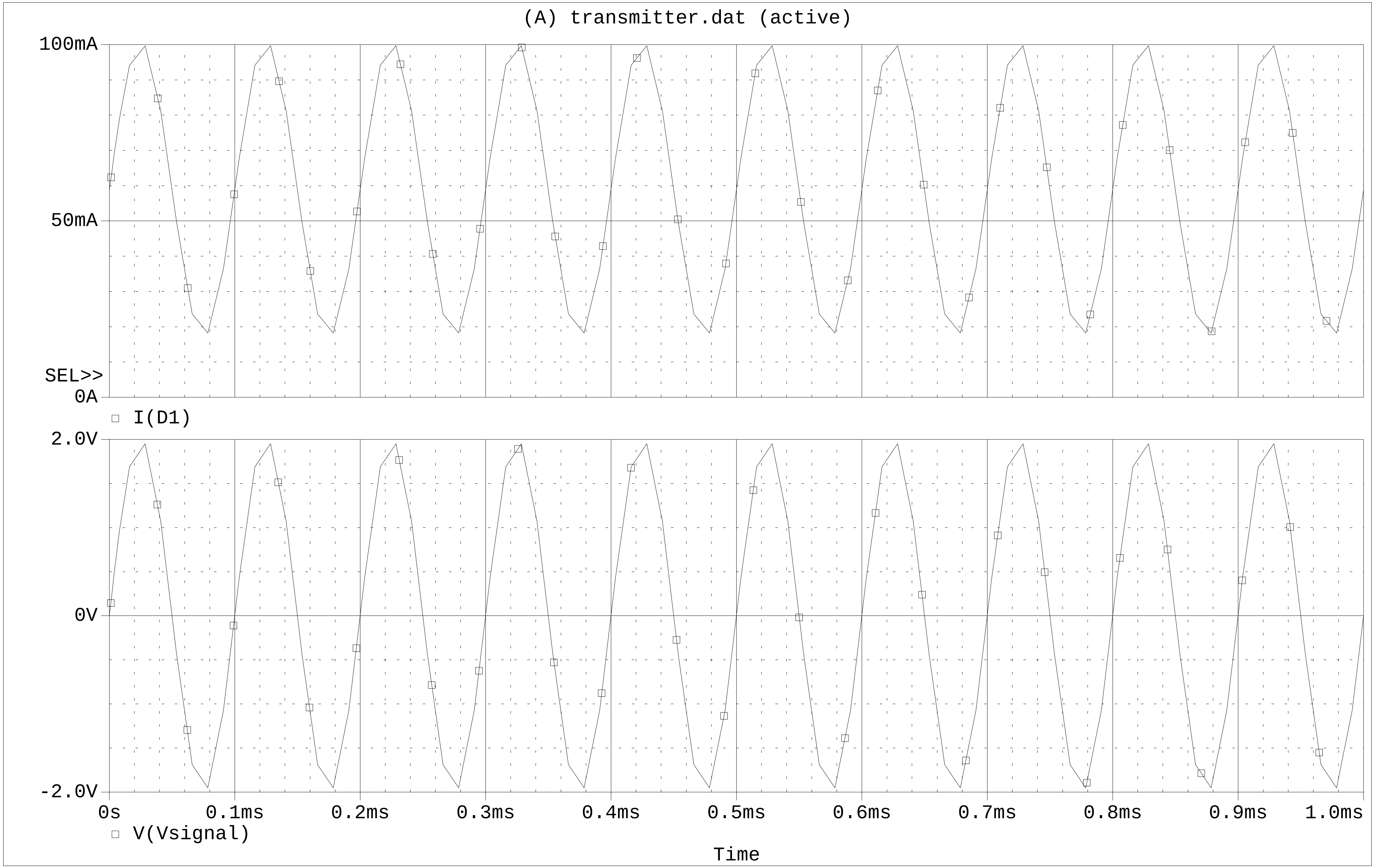

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6. Receiver Front End Design

The front end of and optical wireless receiver is the main limiting factor of an optical data link.

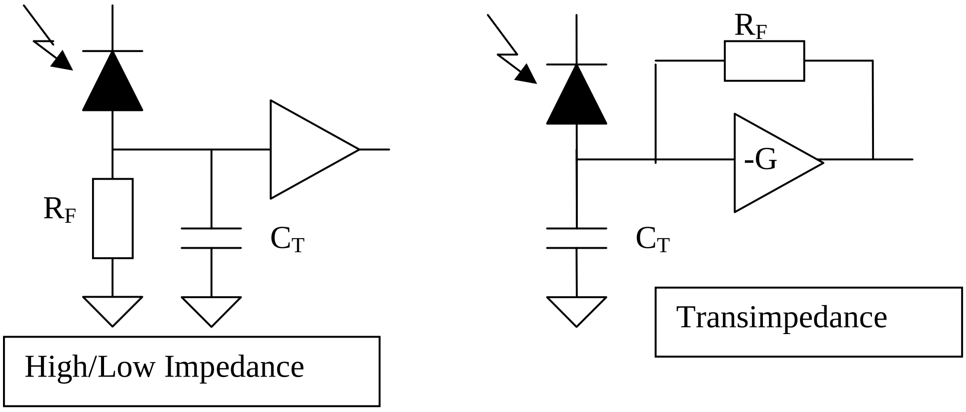

Figure 9 - Receiver front-end configurations

There are 3 basic types of pre-amplifier design that can be used for the receiver front end, low impedance, high impedance and transimpedance. Of these the low impedance design is the most straightforward and allows for a high bandwidth but is best avoided due to the low sensitivity. This leaves the high impedance and transimpedance designs.

In the high impedance design R_F is large and a high impedance FET or BJT input is typically used to amplify the voltage produced by the load resistor. The high impedance design does provide the greatest sensitivity and lowest noise of the 3 designs, although at the expense of bandwidth.

Since the circuit still uses a fixed resistor to convert the current to a voltage it is prone to saturation and interference from ambient light, hence the need for optical filtering. Equalisation is also required to enable a high impedance configuration to realise high bandwidths by cancelling the integrating effect of the preamplifier.

In the transimpedance design a high impedance amplifier is used in conjunction with negative feedback. The most noticeable improvement the transimpedance amplifier has over the high impedance circuit is the cancelling effect of the circuit wiring and diode capacitance.[7] This effectively lower capacitance allows the circuit to realise a

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[7] Page 302 Keiser, Gerd E., *Optical fiber communications*, McGraw-Hill, 1991

higher bandwidth than the high impedance design. The transimpedance design is still however susceptible to saturation and design is more complex due to the possibility of oscillation.

Since a very high bandwidth is not required by the receiver a high impedance front end will be used. This will be based on a single JFET and the circuit is shown below:

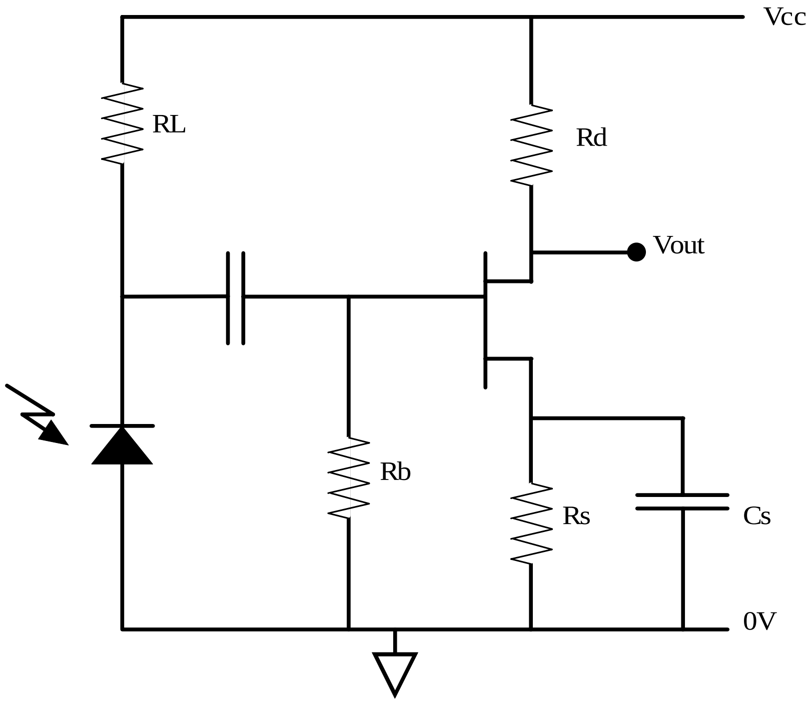

Figure 10 - JFET Based High Impedance Pre-Amplifier

This is a standard single-stage auto biased common source JFET amplifier and will give a gain of around 10. RL is used to convert the photo current to a voltage. This voltage is then amplified by the capacitively coupled JFET amplifier before being passed on to the rest of the circuitry, the bulk of the gain being provided by the post amplifier. Rb is used to auto-bias the amplifier, an added advantage of a FET based amplifier over its BJT equivalent which requires a separate biasing arrangement.

6.1 FET Selection

A low noise FET is required for use as the first stage of the amplifier. For high bitrate (Gbps) optical fiber receivers, low noise GaAs MESFETs are used, but for lower frequencies silicon MOSFETs or JFETs provide adequate performance.[8] The FET

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[8] Page 299, Keiser, Gerd E., *Optical fiber communications*, McGraw-Hill, 1991

chosen is the 2N3819 N-Channel JFET. The 2N3819 is a low-cost, all-purpose JFET which offers; Wideband High Gain, Very Low Noise, Very Low Distortion, Very High System Sensitivity and High low-level Signal Amplification[9]. This easily provides the performance required at the relatively low frequencies used in testing.

6.2 JFET Amplifier Design and Simulation

The DC operating point of the 2N3819 must first be set. There are a number of factors to consider when choosing the operating point. The amplifier must work in the linear region to minimise the amount of signal distortion. The optimal region for the JFET is in the constant current region. The amplifiers should be designed to operate through its maximum range. If the Q point is too close to the pinchoff voltage, or the supply voltage, the signal will clip much sooner, although since small signals will be used this is less relevant. However, for these two reasons, the device will set up to operate at midpoint bias. This means that the JFET is biased so that the drain-source voltage is halfway between the supply voltage and the pinchoff voltage. Taking the pinchoff voltage to be approximately 2V and with the supply voltage at 12V this sets the operating point at 7V.

Another concern of the circuit is power consumption. Since the DC bias of the circuit consumes a certain amount of power that is not "useful" to the circuit (i.e. output as signal power), the power consumption should be minimised. This can be done by using as small a drain current as necessary. A drain current of approximately 3mA is chosen.

The operation point has been chosen as V_{DS} = 7V and I_D = 3mA. This means the remaining 5V has to be dropped across the drain resistor R_D.

This gives $R_D = 5/3\text{x}10^{-3} \approx 1.5\text{k}\Omega$.

The auto bias arrangement must be calculated. A 1MΩ resistor is used for R_B (precise value is not important) and a 470Ω is used for R_S. A 100uF capacitor is used across R_S, maintaining the DC bias while bypassing R_S at the signal frequencies This ensures the gain is not reduced by the inclusion of R_S.

The value of R_L was set at 2.2MΩ. This was a compromise so as to give a high enough signal level into the pre-amplifier, while maintaining a sufficient bandwidth.

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[9] 2N3819 Data Sheet See Appendix A

The circuit was simulated in PSPICE using a current source in series with a capacitor as a simple model for the photo diode. A sinusoidal current with a DC component was used to simulate the input signal. The circuit diagram for the simulation is shown in the figure below:

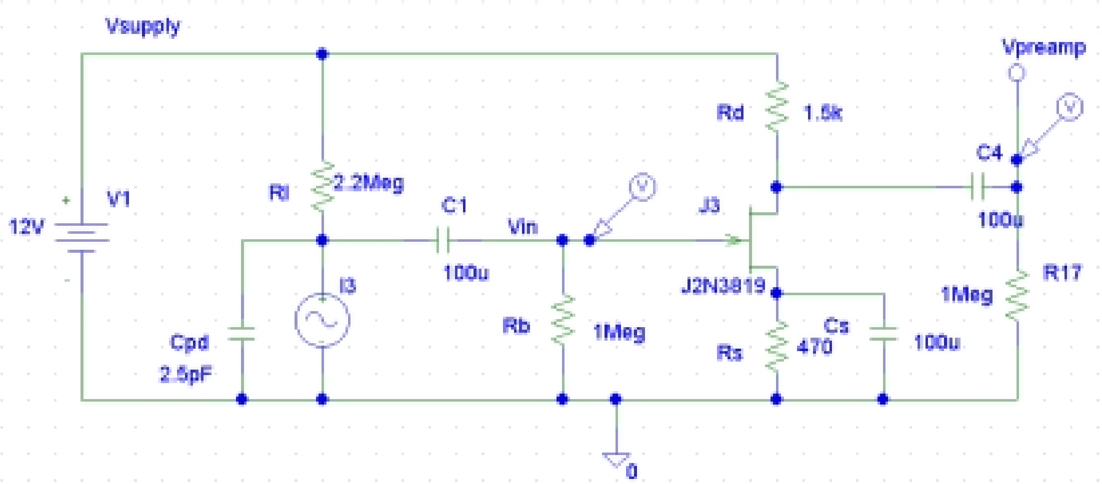

Figure 11 JFET Preamplifier Design

An AC sweep and transient simulations were run and the results were as suspected, with a gain of around 8 as predicted. Figure 12 shows the input and output voltages at the two probes at 10KHz.

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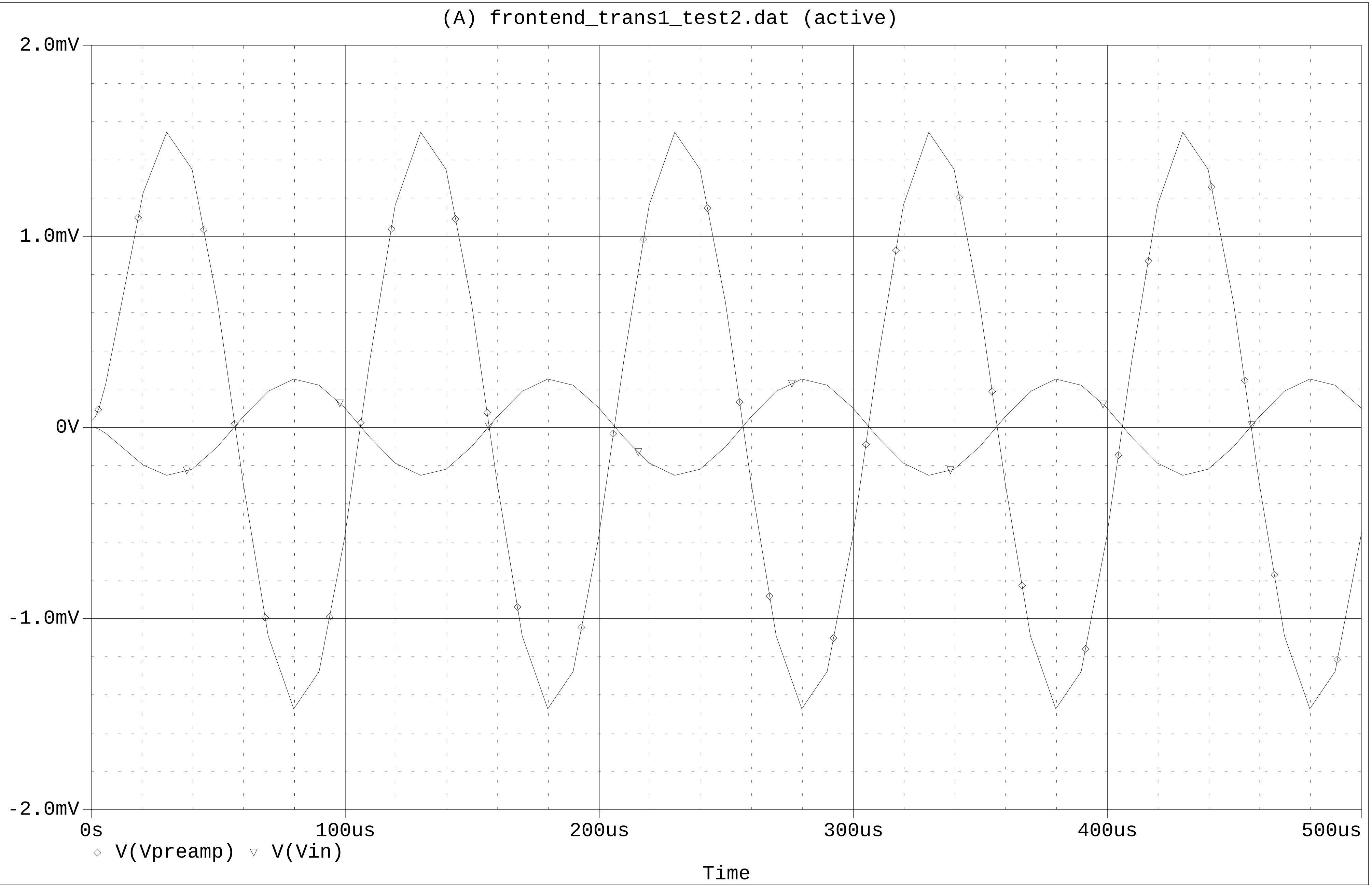

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7. Post Amplifier Design and Simulation

Further amplification of the signal is required to bring the signal level up to a voltage that can be used in detection circuits.

The output from the receiver system should, for testing audio transmission, be at audio line voltage, suitable for input to a hi-fi amplifier or active speakers. This output voltage should therefore be around 2V. A simple op-amp based amplifier can be used. The op-amp must draw minimal current from the circuit so a JFET input op-amp will be used. These have the added advantage of less noise but the shot noise and noise from ambient radiation will mean this noise tends towards irrelevance. A suitable op-amp is the LF411, a low cost, high speed, JFET input operational amplifiers with very low input offset voltage and guaranteed input offset voltage drift. It requires a low supply current yet maintains a large gain bandwidth product and a fast slew rate[10].

A non inverting amplifier arrangement is used so the only current drawn from the preamplifier is the leakage current of the JFET gate, typically in the pA range as opposed to the base current of a BJT which is typically in the nA range.

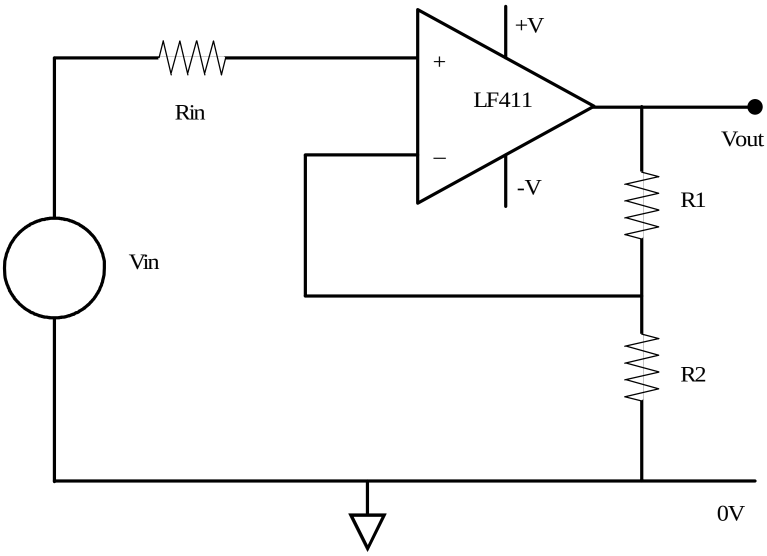

Figure 13 Non-Inverting Amplifier Op-amp Configuration

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[10] LF411 Data Sheet See Appendix A

A gain of 100 is to be used to amplify the voltage to a level where it can be easily measured and observed on an oscilloscope.

The full circuit for simulation in PSPICE is given in figure 14 below:

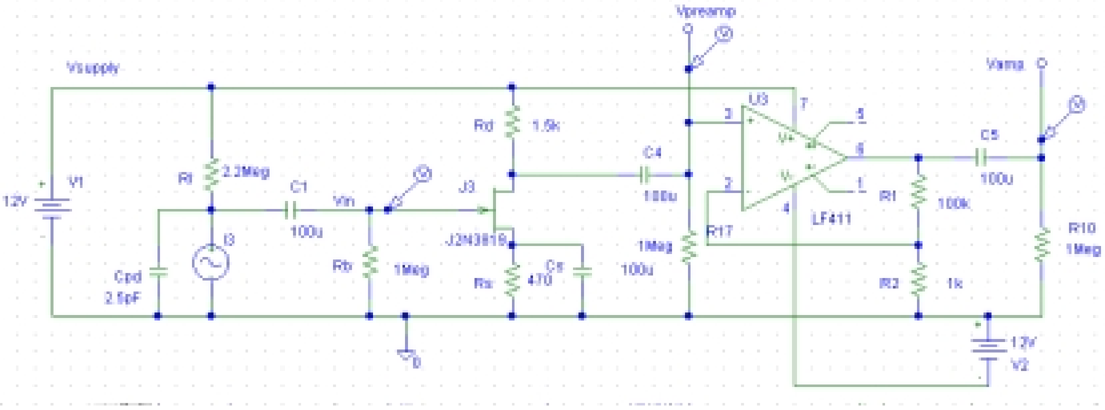

Figure 14 Receiver with pre and main amplifiers

Transient and AC sweep simulations were run on the circuit. The simulation functioned as expected and input/output waveforms were produced. These are shown in Figure 15 Input, pre-amplifier output and main amplifier simulation output.

Figure 15 Input, pre-amplifier output and main amplifier output

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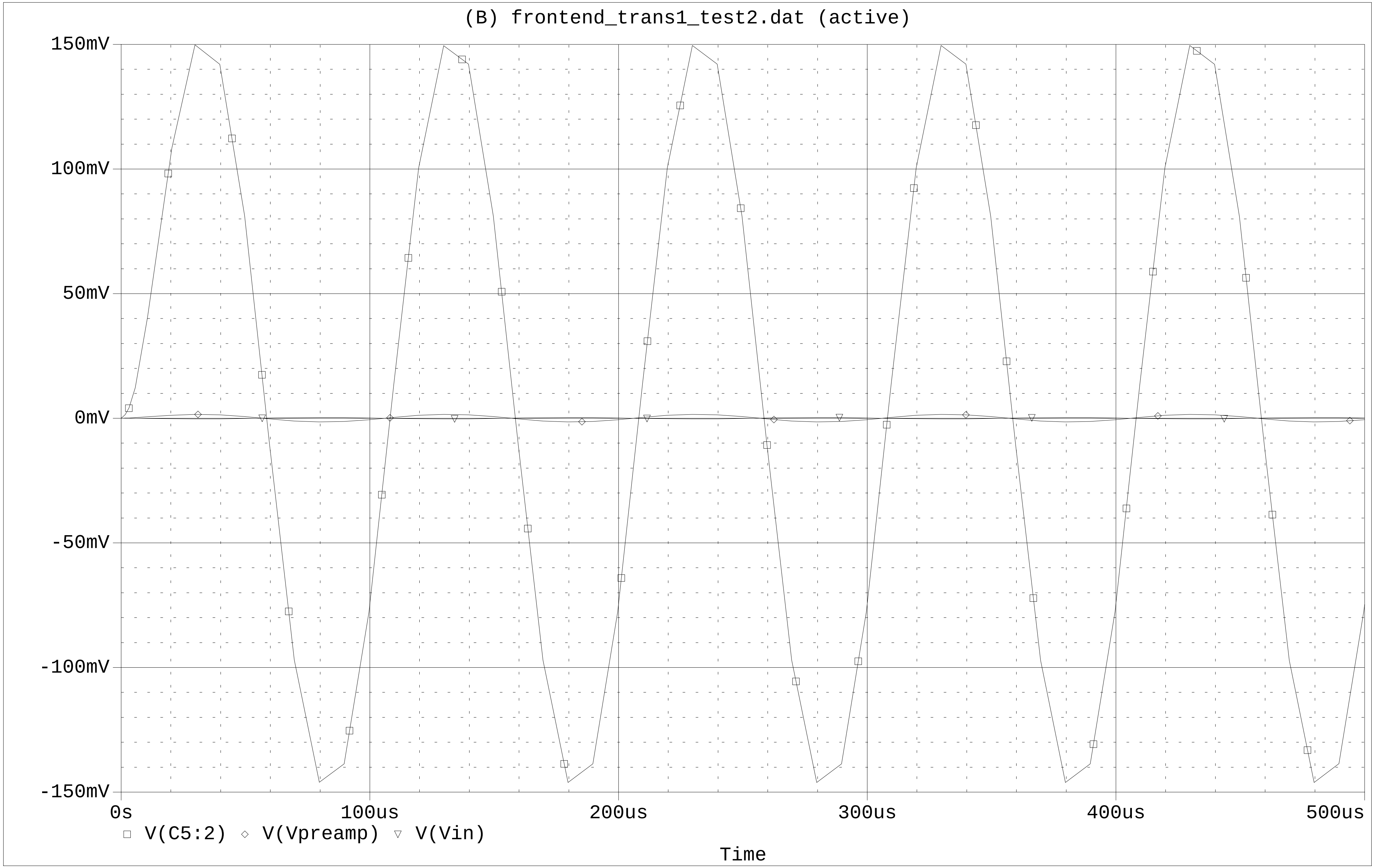

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8. Evaluation and Performance

The transmitter and receiver circuits were assembled on breadboards and tested. A signal generator was used initially as the input signal for the transmitter with a frequency of 10kHz and a sinusoid input of 1.75V (peak). The output from the receiver was observed on an oscilloscope and where necessary measurements were made.

Initially the preamplifier output was measured to confirm its correct operation. When its correct operation was established the main op-amp base amplifiers was assembled and tested since the output from this was easier to measure. The operation of the link was initially investigated by varying the orientation of, and the distance between the transmitter and receiver. The operation was confirmed by observing the received sinusoid altering magnitude in relation to the transmitter and receivers’ relative position.

To test the cut off frequency of the transmitter/receiver the input frequency was swept from 1kHz to 100kHz. Very little attenuation was seen up to around 50Hz but the signal strength reduced rapidly after about 60kHz with the signal being virtually undetectable over the noise at 100kHz.

The effect of distance on the received signal level was investigated and graphs are shown in figures 16 and 17. As expected the relationship follows an inverse square shape.

Figure 17’s (main amplifier) results were measured using the optical antenna and figure 16’s (pre-amplifier) were measured without the optical antenna. While the optical antenna was seen to attenuate the signal at short distances the received signal was stronger when using the optical antenna at the further distances (approaching 50cm), assuming the output from the antenna was correctly oriented with the active area of the photodiode.

It can be seen from to photograph of the input and output waveforms in figure 18, (transmitter input 1.75V at 10Hz with 5cm transmitter-receiver spacing) that even at close range the noise on the receiver output is considerable. At distances of past 50cm the signal was weak and the SNR high, making it difficult to measure the signal voltage accurately.

The main source of this noise is ambient light and shot noise in the photo diode. The noise due to ambient light can be reduced using an optical bandpass filter as shown previously in figure 4. The shot noise in a system is given by:

$$I_{SH}{}^{2} = 2eIB$$

A lowpass filter could be used to remove a proportion of this noise as its frequency distribution largely lies above the frequency range of interest. A simple capacitor/resistor arrangement should be sufficient to achieve this with the cut-off frequency being given by the following simple expression:

$$f_C = \frac{1}{2\pi RC}$$

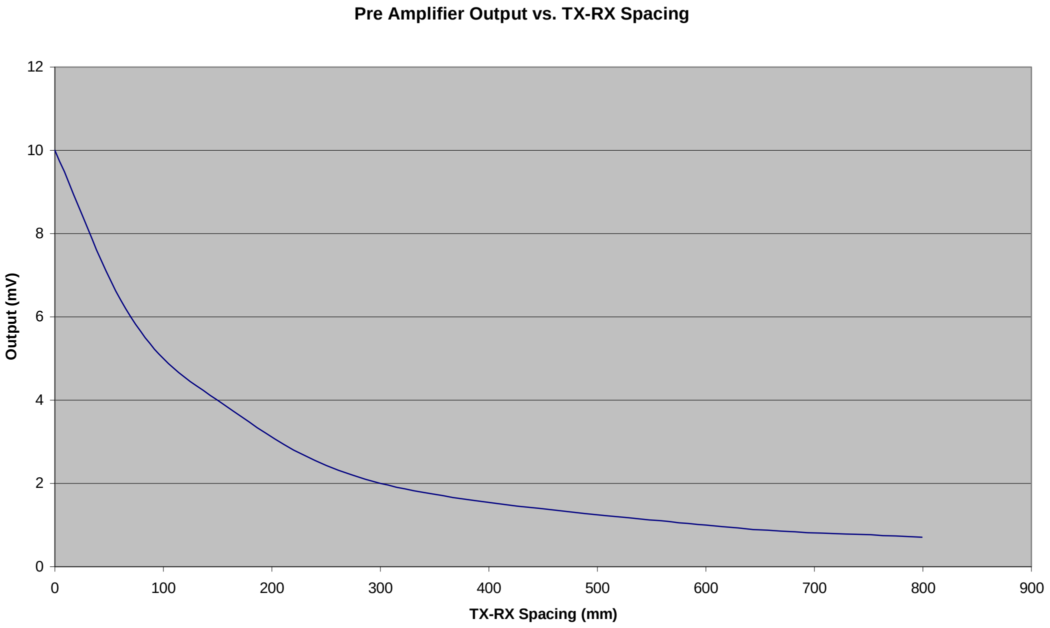

Figure 16 Preamplifier output voltage vs. Distance from transmitter

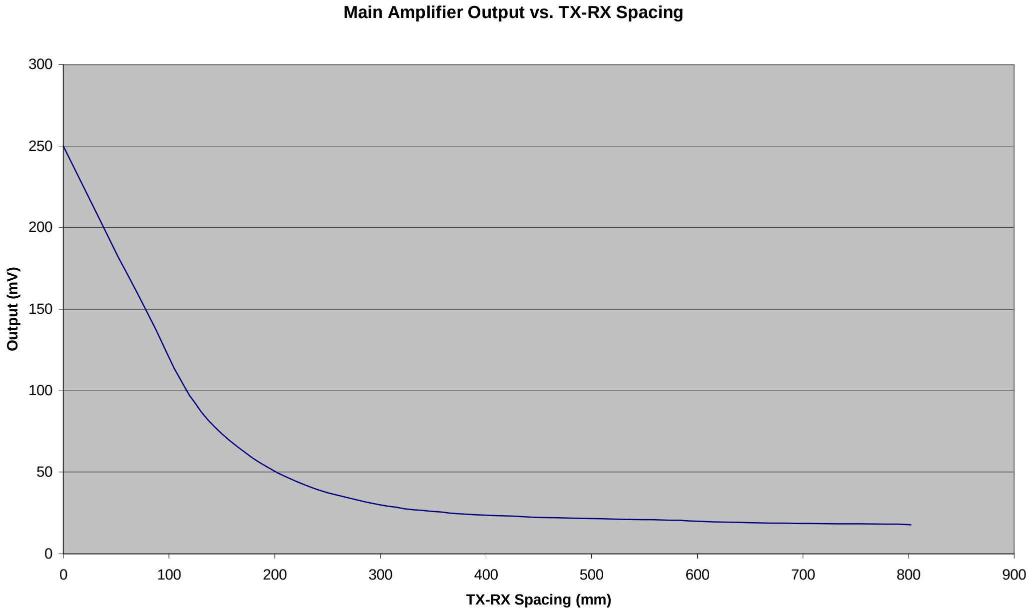

Figure 17 Main Amplifier output voltage vs. Distance from transmitter

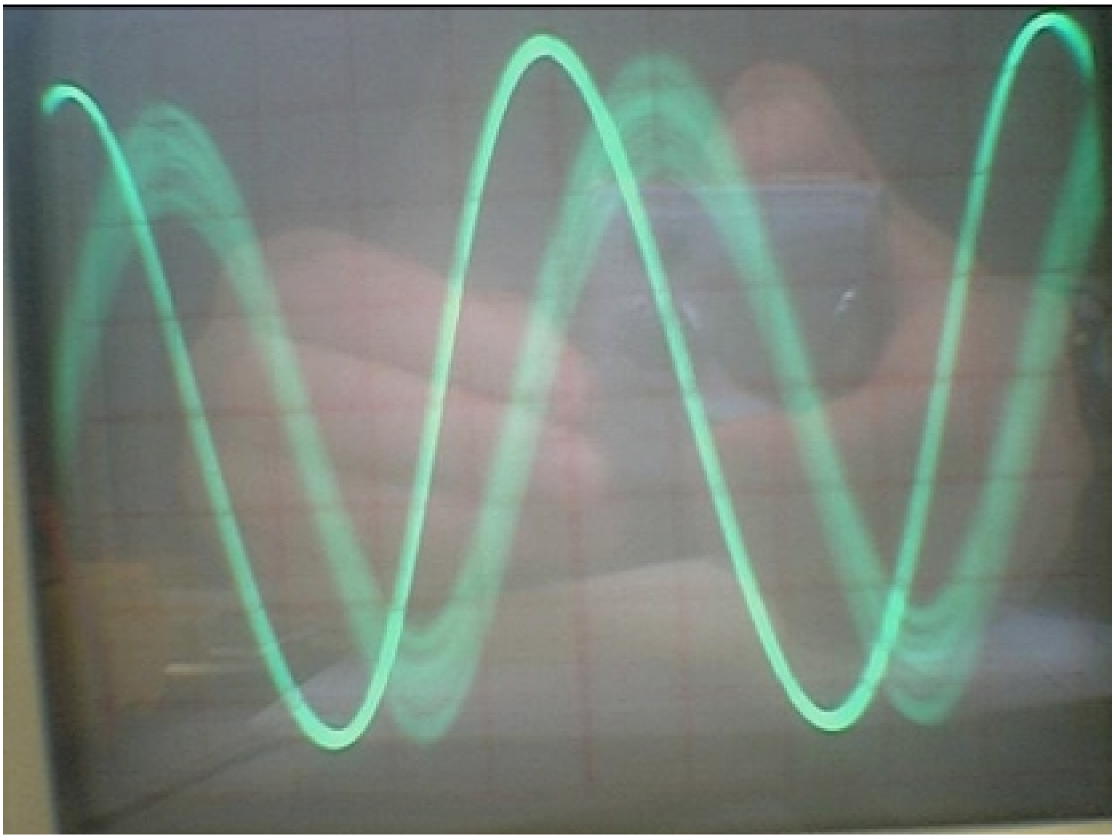

Figure 18 Input/Output Waveforms (1.75V 10kHz input, 5cm TX-RX Spacing)

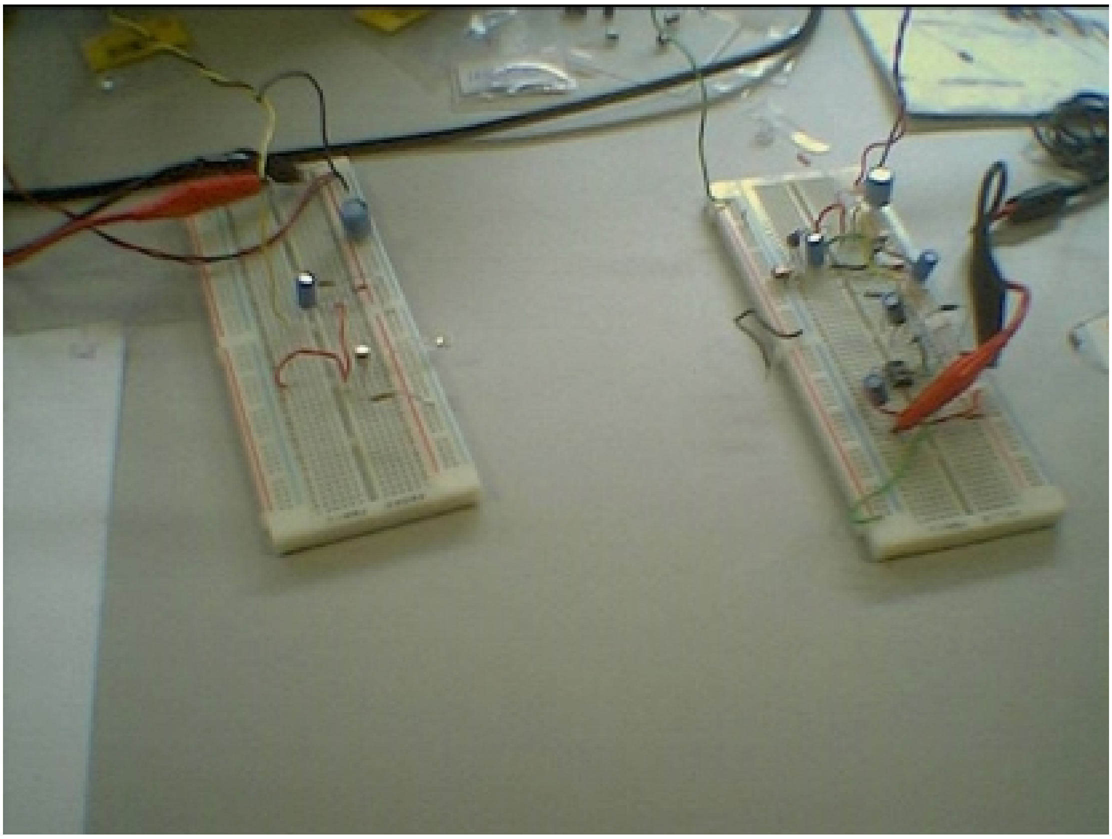

Figure 19 Prototyping and testing

To complete the testing baseband audio was sent across the link. A portable music player was connected directly to the transmitter circuit, allowing the audio to directly modulate the LED. To test the audio output a second amplifier, a LM741 op-amp, again in a non-inverting configuration was added and the gain set to give an output of about 1.5V. The full circuit is shown in the figure below:

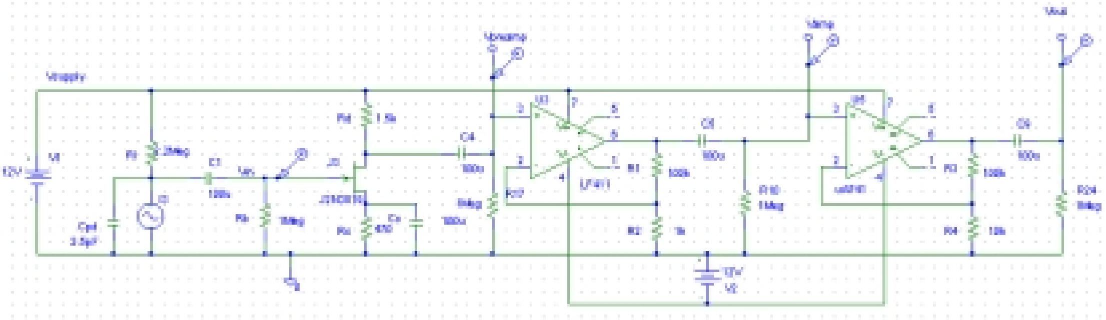

Figure 20 Receiver configuration for testing of audio transmission

The output from this op-amp was sufficient to drive a set of small headphones though a speaker would obviously require additional drive electronics, e.g. a push pull arrangement.

The sound heard in the headphones was recognisable as the original music. The majority of the high frequency noise was obviously inaudible due to the low pass behaviour of the speakers but lower frequency noise could be heard. The noise at the lower audible frequencies was most apparent. The performance of the link in transmitting baseband audio was far from satisfactory for general application but it was possible to confirm that the link was operational as audible and recognisable audio could be heard above the noise.

9. Further Modifications

9.1 Transmitter

The transmitter is only designed as a simple test transmitter and so further modification is not required. However it may be appropriate to add some voltage limiting arrangement for the input signal to ensure the LED does not exceed the rated forward current of 100mA. Naturally it would be possible to use a completely different style of transmitter with the same receiver. The simplest transmitter transmits just pulses of light as used in many optical fiber communication systems.

This would of course mean a further distance could be traversed but switching problems are then encountered as the speed increases.

9.2 Optical Filter

The addition of an optical bandpass filter between the optical antenna in the photodiode would result in a less noisy signal as the response from unwanted wavelengths would be filtered out. This effectively removes the receiver's sensitivity to the visible part of the spectrum, allowing only the wavelengths of the emitter to reach the photodiode. (See figure 4)

9.3 Equalisation

Equalisation is required in high bandwidth systems to recover bandwidth lost by the integrating effect of the receiver's preamplifier (In pulsed operation). This is not really necessary for the receiver in its current operating conditions but may be required for higher frequency applications. A simple resistor-capacitor network is sufficient to perform the equalisation.

A possible circuit to perform the equalisation is shown in the figure below:

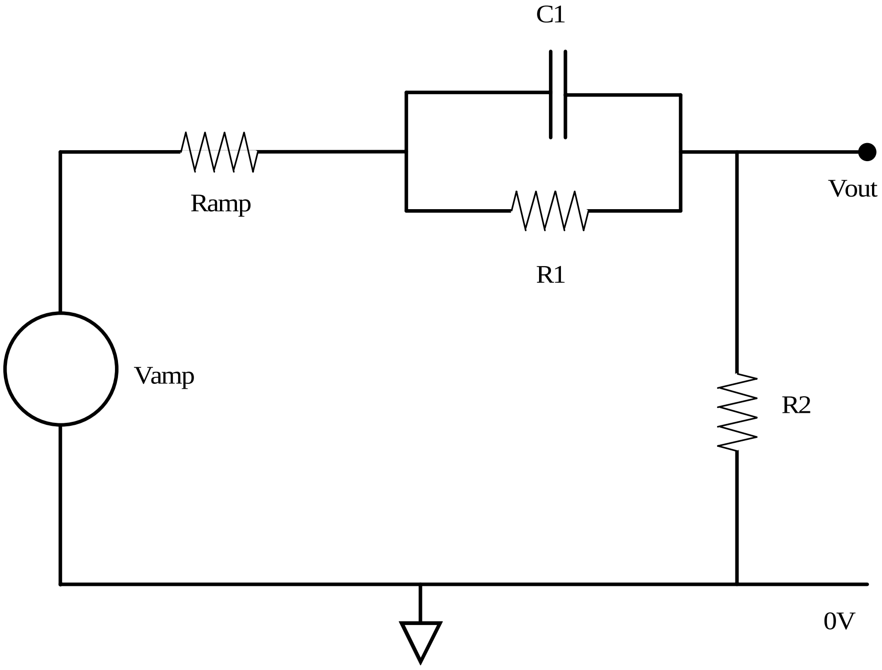

Figure 21 Possible Equalisation Circuit

9.4 AGC (Automatic Gain Control)

Automatic gain control is used in optical and radio receiver systems to provide a standard signal level for received signal so the signal can be demodulated, detected etc. The automatic gain control works on the principle of a voltage-controlled resistance to change the resistance of a proportion of the circuit. This can be used in the feedback arrangement of an amplifier, or as an attenuator to provide a signal with a set peak level from a variable level input signal. This compensates for the variable attenuation in the transmission path, this is particularly important in an optical wireless system.

An example AGC circuit is shown in the figure below:

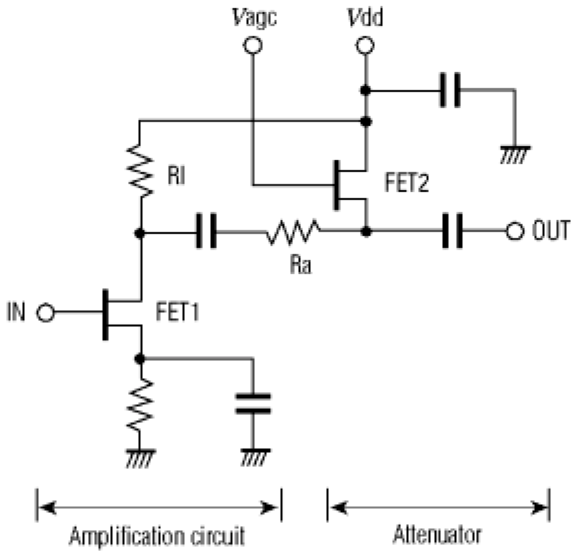

Figure 22 FET Based AGC Circuit[11]

This amplifier consists of a common source amplification circuit and an attenuator circuit. The source and drain of FET2 have the same potential, and operate as a variable resistor. High frequency signals amplified by the common source circuit are divided by resistor R_a and FET2, which are inserted into the signal line, and then output. The attenuator circuit attenuates the amplified signals and varies the load of the amplification circuit.

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[11] Oki Technical Review - http://www.oki.com/en/otr/html/nf/otr-158-9-fig-2.html

9.5 Data Transmission and Detection

The final stage of a digital receiver system is the recovery of the digital data.

The following figure shows a block diagram for a general (high impedance) digital receiver system:

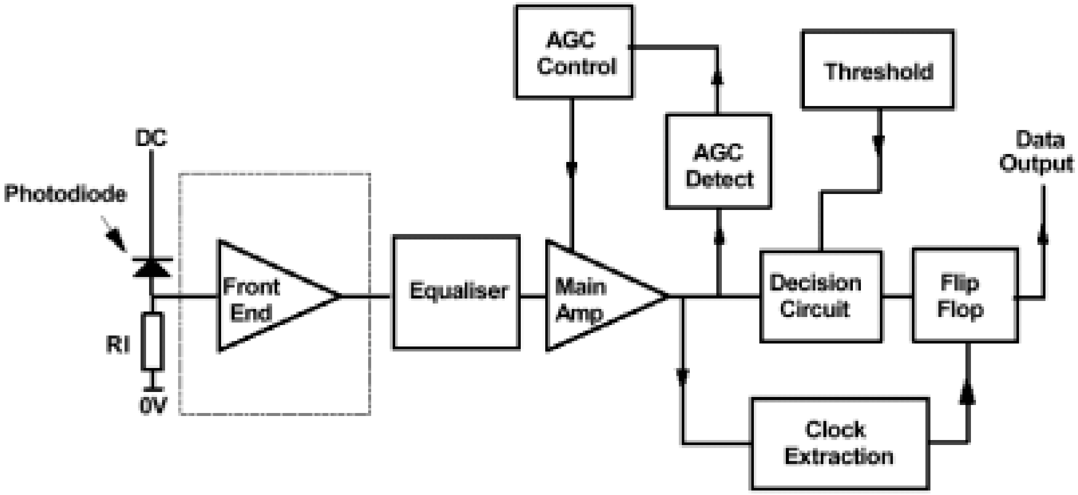

Figure 23 Digital Optical Receiver Block Diagram

After equalisation and the AGC the digital data must be recovered. It is necessary to recover the clock signal from the signal, as a locally generated clock signal would not be sufficient to resolve the data. The decision circuit depends on the method of transmission and would give an on/off logic value representing the received signal. A register flip-flop controlled by the clock signal is used to buffer the data for use by the external circuitry. Naturally the operation of the clock extraction and decision circuit depend on the type of modulation/keying used to transmit the data with many types available including simple on off keying, PWM (pulse width modulation), PTM (pulse-time modulation) and even QPSK (quadrature phase-shift keying).

10. Conclusions

The main proportion of the project is fully completed. A working optical wireless link has been produced over which information can be sent. The operation of the project can be simply demonstrated by the transmission of audio across the link.

The functioning link was noisier than desired but this could be at least partially remedied using an optical bandpass filter.

The receiver used a single stage high impedance JFET amplifier. After designing and building the receiver it has become apparent that although this type of design is perfectly feasible a transimpedance design is likely to perform better. Although a potentially operational unidirectional IrDA link was produced, the results were not ideal and therefore the performance is likely to fall short of the IrDA requirements using the current transmitter/receiver system (see www.IrDA.org). Hence improvements, additions and modifications to the system were considered.

The most significant conclusion for the project was the overall simplicity and low cost of producing an optical wireless link transmitter/receiver compared to its radio frequency counterparts and the potential this offers in the present and future.

11. Table of Figures

12. Bibliography

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13. Appendices

Appendix A: Component Datasheets

BPX65	**PIN Photodiode**
HIRL5015	**High Power Infrared Emitter, 5mm, IrDA 1.0 compliant**
2N2222	**Silicon NPN transistor**
2N3819	**N-Channel JFET**
LF411	**Low Offset, Low Drift JFET Input Operational Amplifier**