

Several years ago the Property Committee of Germantown Friends Meeting installed a sound system for the meeting room. It has been very successful. Here is an outline and some of the relevant details:

#### The GMM Infrared Audio system: Overview

The infrared audio system is a supplement for those who need aid in hearing spoken messages in the Meetinghouse. The audio system has several components. A stereo microphone is located on the Meeting room wall behind the facing bench. This microphone picks up speech from everywhere in the Meeting room. The signal is transmitted to a sound processor and then to the infrared transmitter, which sends the infrared signal to the ceiling where it reflects everywhere in the room. Anyone attending Meeting can sign out a headset and wear it during regular First-day services or special occasions such as weddings or memorial services. The headset picks up the stereo infrared signal from the ceiling and amplifies it for each ear. The headset has a volume control so you can control how loud the sound is. Since the microphones are very sensitive, if the volume control on the headset is turned up one may notice background noise such as the furnace, people coughing, traffic on the streets outside, or children playing. To avoid hearing this type of background noise, the headset can be removed when no message is being given. The headsets are powered by rechargeable batteries so it is necessary to charge them after use.

#### Components of the GMM sound system

The GMM sound system consists of a stereo microphone, preamplifier, sound compressor, infrared modulator, infrared emitter, and several types of infrared headphone. The infrared transmitter components are made by Sennheiser, and are widely used by museums and performance halls.

We have found that our audio system helps the hearing-impaired and also any normal-hearing listener when the speaker is standing in front of the listener, but facing away from the listener, e.g. when the listener is sitting in back of the meeting room.

Our meeting room has a slight ambiance or echo which is good for music but makes hearing someone across the room difficult. We have found that our sound system amplifies the direct sound above the ambiance which greatly helps in understanding the spoken words. There is only a bass cut filter (300 Hz), otherwise the sound can be described as hi-fi: flat from 300 Hz - 20 KHz.

The advantage of a stereo system is that the listener can localize the position of the speaker. This is very important when the voice is soft and there is background noise -- it can make the difference between establishing that someone is speaking, and identifying and comprehending their words. Many hearing-impaired systems provide only monophonic sound which we have found are not as helpful with background noise.

The advantage of an infrared system is that the signal doesn't go beyond the walls of the room. This is helpful for a) privacy, and b) to allow several different adjoining rooms to have different infrared signals that don't interfere. RF-based (radio wireless) systems can be stereo as well, but don't offer privacy or separation between rooms. The IR system can be directly connected to a hearing-aid FM system.

For a hearing-impaired person who wears a hearing aid, if the hearing aid is only monophonic, the stereo system would not add anything but would still be compatible, and a stereo system would still be of advantage to those who could wear stereo headsets. The hearing impaired person can choose between simply removing the hearing aid to use a headset, or can connect a hearing aid that has an input jack to the IR system with the Sennheiser RI-810-S IR receiver which has a 1/8" stereo jack output (see below).

List of components:

Electret condenser boundary microphones (2)  
Microphone preamplifiers (2)  
Microphone preamplifier power supply (1)  
Audio compressor (Alesis 3630 dual channel compressor limiter with gate) (alternate: Alesis 3632)  
Infrared modulator, Sennheiser SI-1015, 2-channel  
Infrared emitter, Sennheiser SZI-1029-24, with 24V power supply

Infrared headsets (to operate with 2.3/2.8 MHz infrared signals):

Sennheiser RI-830 - stethoscope style with large volume dial, automatic switch.  
Sennheiser RI-810-S - with headphone jack, for induction neck loop or hearing aid input.  
Sony MDR-IF245RK - headphone style with volume, separate switch. Excellent quality

Ooku Two Channel Folding Universal Rear Entertainment System Infrared Headphones Wireless IR DVD  
Player Head Phones for in Car TV Video Audio Listening -- less expensive  
<http://www.amazon.com/Universal-Entertainment-Infrared-Headphones-Listening/dp/B009VDPQE2>

### Microphones and placement

The advantage of using PZM ("boundary") microphones in a meeting room is that they give better reception of direct signals over the background ambiance than a normal microphone. This greatly helps in hearing softly-spoken messages. If you are interested, see the attached .pdf file (2 MB) describing the theory for PZM microphones.

We have mounted the microphones on the wall just behind the facing bench, which is 90' feet from the rear of the meeting. This placement is a compromise: the speaker on the facing bench is speaking away from the microphones, but is close to them. Speakers in the meeting room are located far away. However, we have found this compromise to work well, because a person speaking from the facing bench is close and people speaking from elsewhere in the room, although they are farther away, are directly facing the microphones. This works very nicely when there is only one speaker (i.e. with a meeting for worship or a conference) -- but of course would not work well where there is more than 1 person speaking or for music where mics could be more optimally placed.

Microphones could also be placed at several different sites in the meeting room but then would need to be mixed together. Because our system is stereo, it might be difficult to mix together several microphones to give good stereo, so we have kept the system very simple by including only one stereo pair. This gives the stereo sound very good directionality. Usually Meeting speakers face towards the center front of the meeting room, which is where our microphones are placed.

The loudness must be set to pick up soft voices and these can be easily drowned out by background noise (coughing, furnace, road and airplane noise, etc.). A sound compressor is included in our system, which is helpful to limit the loudness for sharp or very loud sounds which might damage the ears. Our sound compressor also has a "gate" which can shut off the sound when nobody is speaking. However, we have found that while the sound gate is helpful it usually feels better to have the sound going continuously during Meeting -- the headphone wearer gets used to the background noise.

Boundary (or Pressure Zone) microphones generate an enhanced signal for sound sources at a distance. The microphone cartridges are installed on the wall behind the facing benches mounted face down on a sheet of plexiglass about 1 mm above the surface. This provides enhanced sensitivity, frequency response (10 Hz - 20 kHz) and omni-directionality. The microphones are placed about 12" apart which gives an excellent stereo image in the headphones, important to allow the sound from someone speaking to be discriminated from background noise. The microphones are "electret condenser" cartridges and require power (5-9 volts, varies

depending on the exact type) and are "low-level", meaning that their signal must be amplified by 50-100x to "line level" in order to be adequate for the sound processor system. This is described in more detail below.

### Sound processor

The signal from the microphone preamplifiers is passed into the sound processor (Alesis 3630 compressor/limiter) which reduces loudness fluctuations when the microphones pick up loud sounds. The processor has two identical sets of controls on its front panel, on the left and right sides. Each set controls one of the channels, but for stereo a push button in the center causes the right side controls to be set by the left side controls (leave the push pressed in to enable this feature). On each side, at the left, the "Threshold" knob sets the sound level at which compression starts to take place, i.e. above this level the compressor reduces the loudness of the sound to make it more constant. We have set this threshold knob to start compressing at a little louder than a typical voice. The compression is indicated by a line of red LEDs below the knob. Next, the "Ratio" knob sets how much compression, i.e. 1:1 means no compression, and 20:1 means a lot of compression. We have set this knob at 6:1 - 10:1, or a moderate amount of compression. Next, the "Attack" knob sets how fast the compression occurs after a loud sound is detected. We have set the attack time to 5-10 ms. Next the "Release" knob sets how long the compression lasts after the loud sound is gone. We have set the release time to 200-500 ms. Next, the "Output" knob sets the amplification of the sound going to the headsets. We have this set a little below maximum to allow the headsets to give a loud signal but not so high to cause distortion of the signal in the infrared system. The input/output level (set by a button) is displayed on a line of green LEDs below the knob. There are 2 more knobs to the right that control the "sound gate" feature. The first one, "Gate Threshold" sets the level at which the sound gate allows sound signals to pass. If the sound is weaker than set on the threshold, the gate turns off and no sound passes to the output. The "Rate" knob sets the time after a sound for which the gate stays on. When the Gate is set to activate (by turning up the knob so the red light underneath goes on), background noise is reduced but the sound becomes "choppy", going on while someone speaks, then off quickly, tending to confuse the headset listener. Therefore we have the "Gate Threshold" knob set to "off", i.e. no gating, always on.

### Infrared modulator

The sound from the audio processor is connected to the infrared modulator (Sennheiser SI-1015, 2 channels). This changes the signal from a line level audio signal into a stereo radio-frequency signal (2.3 and 2.8 MHz, frequency modulation). The modulator has loudness controls for both channels. We have set these controls to near maximum to keep gain high without distortion. The modulator outputs both channels into each output socket (BNC) at the back, and passes the signal through 50-ohm (RG58U) cable. In addition the modulator has a connection block at the back to power the infrared emitter remotely. Both modulator and emitter run on the same power supply, and the modulator can power 1 SZI-1029-24 emitter (24VDC, 1.65 A). The power wire to the emitter is a 2-conductor #14 speaker wire.

The power supply is a 24VDC, 2.5 A power supply (Sennheiser NT1015 or Jameco 161605).

### Infrared emitter

The wire from the infrared modulator passes down into the basement and then up through the east wall of the Meetinghouse to the window above the door where the infrared emitter is located. The emitter (Sennheiser SZI-1029-24) receives the radio frequency signal from the modulator and converts it to infrared light (880 nm) with 100 infrared LEDs, emitting 5 watts of infrared power. The infrared is emitted at a fairly wide angle (30-40 degrees) and we have set it to point to the center of the ceiling. This allows the infrared beam to be received by a headset anywhere in the Meeting room. The emitter generates quite a bit of heat (~25 watts) and this heat must be dissipated from heat sinks on its back and sides. Therefore the emitter cannot be enclosed in a tight box. The LEDs can be seen to glow deep red when emitting infrared. When the emitter has 24V power but no signal, it turns off its infrared LEDs and displays a bright red light indicating that it is not operational. If some of the LEDs are not working the emitter can still function but when too many of its LEDs do not function the red

indicator light will come on. The emitter can be sent back to the manufacturer to replace the LEDs. When it is fully operational a green light comes on (the normal case).

A good choice for the infrared modulator is:

Sennheiser SI-1015 (\$795)

and an infrared emitter:

Sennheiser SZI-1015T (\$890) - for a medium size room (up to 4000 sq ft)

or

Sennheiser SZI-1029 (\$2,200) for a large size room (12,500 sq ft).

SZI-1029-24 is the same but is powered remotely by 24 V for mounting high on a wall or ceiling.

Or you might make do with a:

Sennheiser SI-30 infrared modulator/emitter (\$329) and power supply NT20-4 (\$85) which is for conference rooms. (available from [www.bhphoto.com](http://www.bhphoto.com)) The SI-30 is a modulator/emitter that can be used for up to 750 sq ft.

or possibly a smaller system might do:

The Sony MDR-IF245RK (\$40), includes an IR headset that and also an IR transmitter for use with TV at home. The IR transmitter could be set up on one side of the meeting room and the listener would need to sit within 20' direct sight of the IR transmitter (see below). This might work for several listeners if they all sat close enough to the transmitter with a direct line of sight. Or maybe if the ceiling is low enough the signal from the IF245RK could be pointed to the ceiling to allow the listener to sit anywhere.

These Sennheiser components can be purchased from [amazon.com](http://amazon.com) or [bhphotovideo.com](http://bhphotovideo.com). They may require several weeks to arrive because they are not always carried in stock. I recommend [www.bhphotovideo.com](http://www.bhphotovideo.com) because they are a very professional store in NYC -- you can purchase off the web page or you can call on the phone. They can sell you a complete IR system (SI-30, IF-245 or RI-810 headphones, NT20-4 pwr supply, or the SZI-1015 and SZI-1029).

The sound compressor (Alesis 3632, replaces older 3630, or equivalent) can be purchased from [www.amazon.com](http://www.amazon.com) or [www.musiciansfriend.com](http://www.musiciansfriend.com) for \$140.

The microphones are "PZM" ("Pressure Zone Microphone") (also called "boundary") microphones. They can be purchased or constructed.

You might also try normal stereo microphones, such as Crown Sound Grabber II PZM condenser microphones -- 2 for \$120 at [www.amazon.com](http://www.amazon.com) or [www.musiciansfriend.com](http://www.musiciansfriend.com). or Crown PZM-30D \$288, 2 for \$576 (stereo) at [www.amazon.com](http://www.amazon.com)

However, the PZM microphones give a 6 dB gain advantage over normal microphones. The PZM description file (attached) describes this advantage in detail.

The preamplifier can be almost any stereo model with "phantom power" (to power the microphones):

M-Audio Audio Buddy Budget Stereo Microphone Preamp:

<http://www.amazon.com/M-Audio-Audio-Budget-Microphone-Preamp/dp/B000CZ0RZG>

\$76 at [www.amazon.com](http://www.amazon.com) or [www.musiciansfriend.com](http://www.musiciansfriend.com). Instead of purchasing a preamp, we made custom preamplifiers that are phantom powered (the power comes down the audio cable), using low-noise op-amps. The circuit components are about \$50/channel. If you are interested I can explain more about this.

The microphone placement is critical. They should be mounted on a wall at head height about 12" apart. The wall mounting gives them better pickup and coverage.

I constructed our microphones from condenser microphone cartridges (Radio Shack #270-090, \$2.99, or Panasonic WM-34, WM-60) glued to a wood cantilever (1/2" x 1/2" x 4"), mounted on plexiglass base (Home Depot). They can be mounted 8-12" apart on the plexiglass, and for better separation between L and R a piece of foam can be placed between them, mimicking the head between the ears.

The electret microphones are powered remotely by the shielded microphone cord which has 3 conductors (signal, power, ground=shield). The microphone cord is plugged into a low-noise microphone preamplifier (gain of 50x using OP-27 or NE5534 operational amplifier chips) powered by a 12 V power supply. The preamplifiers are located near the microphones and powered remotely, and are connected to their power supply through a long (30') cord with 1/4" stereo jacks. The signal transmitted by the preamplifiers is at a "line" level (50 mV) so it will not pick up interference or noise in a long wire run, and can be connected to a standard signal processor.

#### Direct loop transmission to telecoil

It is also fairly easy to install a direct loop amplifier that transmits monophonic sound directly to hearing aids that contain a telecoil. The equipment for this is an "induction loop amplifier" that is designed to be connected directly to a loop of wire around the edge of the room. This transmits a sound signal magnetically to a reception "telecoil" inside some hearing aids. The advantage of this system is that it works automatically with hearing aids once the person walks into the room. One disadvantage is that it is only monophonic, because there is only one channel (i.e. there are no high frequency carriers as on FM audio systems). The loop can be laid out around the edge of the room where the floor meets the wall, or can be installed below the floor in the ceiling of the basement if that is easily accessible and appropriate. The loop audio system can work in parallel with an infrared system like the one described above. Several commercial units are available, see:

<http://www.ampetronic.com/Products/Loop-Amplifiers>

<http://www.assistiveaudio.com/Ampadvice.htm>

<http://www.assistiveaudio.com/ILD252.htm>

<http://www.ovalwindowaudio.com/loopintro.htm>

#### Converter from IR to loop system

It is also possible to purchase infrared receivers that work like those described below (e.g. Sennheiser 830) but instead of an earphone can transmit magnetically through a "neck loop" to the telecoil in the hearing aid. See:

<http://www.amazon.com/Sennheiser-Amplifier-Neckloop-Sets-830S/dp/B006N04LK6>

<http://en-de.sennheiser.com/tv-listening-system-infra-red-hearing-aid-wearers-set-830-s>

#### Headsets

At a normal First-day Meeting for Worship, those who attend the Meeting may pick up a headset from the Meeting Office. At special occasions such as weddings and memorial services, the appropriate committee (Marriage and Funeral Arrangements committees, or Care and Visiting committee members in charge) will oversee the distribution of the headsets with help from the Property Committee. On such occasions, headset use should be planned in advance so that the system can be explained to attenders who are not familiar with it. Several committee members may be needed to explain how to use the headsets if many are requested.

The headsets are stored in the Meeting Office, on the shelf in the computer room. Members and attenders may sign out a headset to use in the Meeting, and after use are responsible for replacing it. There are several styles of headset. One type is similar to a standard headphone with a band that goes over the head and "ear-muffs" that cover the ears. This type is useful if one wears a hearing aid and prefers not to remove it. A second type is the "stethoscope" type that one wears under the chin. Both types give equivalent performance, are powered by the same rechargeable battery type, and have a volume control and a power switch.

The headsets come in several styles -- the "headphone" style (Sony MDR-IF 245RK) that fits over the ear is familiar to many from their hifi or TV sets at home. The "stethoscope" style (Sennheiser RI 830) offers equally good sound but fits into the ear instead of over, and is more discreet because it hangs below the chin. It has a large volume control dial which is easier to use, and has an automatic switch that turns the unit off when removed from the head.

Sennheiser RI-830. This is a stethoscope style headset (same as included in SET-830) that is purchased alone without any base for charging or listening to TV. The big volume dial is easy to turn and the headset is very light and unobtrusive. The headset is worn under the chin and the dial must point away from the body to receive the infrared signal. There is no manual power switch because when the headset is removed from the head the power is switched off automatically (by the angle of the stethoscope). This headset cannot be used with a hearing aid so hearing aids must be removed before wearing it. (\$160 new)

Sennheiser SET-830. This is set containing the RI-830 headset (described above), a base that can plug into a TV set (for watching TV at home quietly), and a power supply. When not in use, the headset is placed back onto the base which charges the headset's battery. (\$250 new)

RI-830-S. For use with an existing hearing aid, the RI-830-S is a stereo IR receiver like the headphones described above, except it has only the receiver without earphones and a standard 1/8" stereo jack which can be used with an inexpensive hifi stereo headset, direct connection to the hearing aid, direct connection to an FM wireless hearing aid transmitter, or with an "induction loop" to transmit to the hearing aid. However most hearing aids are not designed to receive 2 channels (stereo), because each one works with only one ear. If they are connected to receive only a monophonic sound channel, this defeats the purpose of the stereo in providing better sound perception -- but of course one channel is usable. If an FM hearing aid system has only 1 channel it may be preferable to use stereo headphones, either instead of hearing aids in the ears or together with the hearing aids (\$250).

Sony MDR-IF 245RK (replaces: IF 240RK) a "headphone" style headset, less expensive than the RI-830 and higher performance. It has a volume control, a separate power switch, and a red LED light that indicates when the headset is operating. The battery is a NIMH AAA cell that runs for 30 hours. (\$40 new)

A wide variety of infrared headsets designed for car "rear entertainment systems" are compatible with this audio system:

<http://www.amazon.com/Universal-Entertainment-Infrared-Headphones-Listening/dp/B009VDPQE2>

[http://www.amazon.com/s/ref=nb\\_sb\\_ss\\_c\\_0\\_20?url=search-alias%3Dautomotive&field-keywords=infrared%20headphones%20for%20car&srefix=infrared+headphones+%2Caps%2C296](http://www.amazon.com/s/ref=nb_sb_ss_c_0_20?url=search-alias%3Dautomotive&field-keywords=infrared%20headphones%20for%20car&srefix=infrared+headphones+%2Caps%2C296)

## Battery chargers

All the Sennheiser headsets that work with our infrared system use the same type of rechargeable battery (Sennheiser BA-151). The batteries can be charged with the chargers that come with the IS-380 and SET-810 headsets. The batteries must be charged 3x the duration of time that the headsets have been turned on, i.e. for a 1 hour service the batteries must be charged 3 hours. A battery can power the headsets up to 4 hours so it does not need to be recharged after each use, however it should not be allowed to fully discharge. The batteries can remain in the charger indefinitely so they need not be removed when fully charged.

The Sony headsets run with a AAA NIHM rechargeable battery and a standard AA-AAA battery charger is available to charge these batteries.

#### Purchasing headsets

The stethoscope style headsets (Sennheiser RI-830) can be purchased from [www.bhphoto.com](http://www.bhphoto.com) for \$160. Their batteries are made by Sennheiser (BA-300 -- small lithium battery - \$50) and need a special charger -- Sennheiser L300-10, \$384 (charges 10 batteries). These items are available at [www.bhphoto.com](http://www.bhphoto.com) or [amazon.com](http://amazon.com).

The headphone style (Sony MDR-IF245RK, replacement for IF) is available from [www.bhphoto.com](http://www.bhphoto.com) for \$65. I recommend these because they provide equally good sound but are cheaper. They come with an IR transmitter and battery charger. For use in the meeting room to allow the receiver headphones to sit anywhere, the included transmitter is not applicable (because it is not powerful enough) but for a very inexpensive system where one person sits near the transmitter, it might be set up close to the seat, with wires to the mics/preamplifier.

See the Sony MDR-IF245RK headphones at:

<http://www.amazon.com/Sony-MDR-IF245RK-Wireless-IF-Headphone/dp/B009A6CZ26>

[http://www.bhphotovideo.com/c/product/892926-REG/Sony\\_mdri245rk\\_Cordless\\_Stereo\\_Headphone\\_IF.html](http://www.bhphotovideo.com/c/product/892926-REG/Sony_mdri245rk_Cordless_Stereo_Headphone_IF.html)

Siting the infrared transmitter

We have arranged our IR transmitter to point to the middle of the ceiling -- it makes a big spot of infrared. This is not the recommended way (which is to place the IR transmitter up high on the wall pointing down for a direct line of sight). We have found for the meeting room the center ceiling spot works better because it is visible from any position, as long as the listener is sitting facing inwards -- the listener can be facing any direction, on the facing bench or in the benches arranged N-S or E-W. A line of sight arrangement excludes anyone not facing directly towards it.

#### Overview of complete systems:

Depending on what you want, you could set up a system for:

\$200 -- (\$20 homemade mics, \$80 preamps, \$40 headphone with IR transmitter, good for small room where listeners sit within 20' of transmitter)

\$1000 -- (purchase mics \$120, \$80 preamps, \$100 compressor, \$360 IR modulator/transmitter for small room, \$320 for 8 headsets, or \$120 for less expensive car rear entertainment headsets)

\$3000 -- (purchase mics \$600, \$80 preamps, \$100 compressor, \$1500 IR modulator/transmitter for large room, \$160 for 4 headphones, \$480 for 4 stethoscope sets, \$60 for less expensive car rear entertainment headsets)

So, depending on the size of your meeting room, and the configuration of the facing benches relative to the floor layout, there are several systems that would work.

I recommend starting with the simple ~\$200-300 system with 1 or 2 \$40 headphones, and testing it to see whether the IR transmitter included with the headphones would work in the meeting room. Get the microphones and preamp(s), and try this simple system first. The Sony headphones come with their own transmitter, and you can experiment to see the best location for the microphones. Then if there is a central ceiling spot visible to all seats, you can add a higher power IR emitter that points to the ceiling from one of the corners or a windowsill.

#### Advice to users:

Before placing the headset on your ears it is important to know where the volume control is and how to change it. The sound processor limits the loudness of the audio that you hear but if the volume control is set too high you may find the audio too loud. The headset receives its signal from the infrared beam near the center of the ceiling, so to hear the audio you must wear the headset so its front is pointing towards the center of the Meeting room. If you place your hand on top of the headset it cannot receive the signal so it may go quiet. If you hear "static" type noise this indicates a weak signal. Sources of a weak or missing audio signal include: facing away from the center of the Meeting, sitting in direct sunlight, wearing the headset backwards, or the audio system is not turned on.

The battery can power the headset for up to 4 hours on a full charge. After you use the headset, return it to the Meeting Office. To recharge the battery, remove the battery by pulling on its tab and place the battery in one of the charger units located on the shelf in the computer room. It takes about 3 times as long to recharge the battery as the time it was used. In any case it will be fully recharged in 24 hours. The Meeting Secretary in cooperation with the Property Committee will charge the batteries regularly.

Members and attenders who use the headsets regularly may find an advantage in purchasing a headset, to keep it clean and always have it on hand. This type of infrared headset is widely used in theater and other public events so you may use it in other venues. Before deciding to purchase one, you should try out the different headset styles to understand the pros and cons of each. The cost varies between \$15-\$20 (folding car style), \$40 (headphone style), and \$160 (large volume dial, Sennheiser RI-830).

Let me know if you have any questions,

Rob Smith

rob@retina.anatomy.upenn.edu