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Purpose of using various types of pickups for string instruments

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Abstract

In this paper, the indepth study of various types of pickups for string instruments has been done because now a days Indian musicians are using different types of pickups in the sitar, guitar and other instruments instead of microphones. They are using without knowing its nuances and effects. The whole process is amlification of sound coming out from musical instrument. Amplification means process of the sound is converting the sound in to the electrical signal. A unit or the device which converts one form of energy into another form of energy is known as the transducer. There are two familiar types of the transducer as far as the sound wave is concerned, microphone and pickup. Microphones are universally used for speech, vocal music as well as for the instrumental music, but pickups are used only for the instrumental music. Microphones are most common type of the transducer having the nickname Mic or Mike. Microphones are categorized by their transducer principle.The most common are,carbon microphone, dynamic microphone, piezoelectric microphone, laser microphone, fiber optic microphone, and speakers as microphones. A pickup device is a type of transducer (specifically a variable reluctance sensor) that captures or senses mechanical vibrations produced by musical instruments, particularly stringed instruments such as the sitar, electric guitar, electric bass guitar violin etc. and converts them to an electrical signal that is amplified using an instrument amplifier (such as preamp.) Use of pickup gives better feedback and avoids cross talk, covers whole desired frequency range of the string instruments, generating natural tone at the output end. So it is preferred to use pickup than microphone as a transducer for amplification purpose for the sound of string instruments. The objective of this papes is to understand the various types of the pickups and merits of using pickup over microphone for string instruments.

Keywords: Microphone, Pickup, Instrumental Music, Transducer, Sitar

Research Paper

Transducer : Transducer function is to convert the sound into the electrical signal, in order to process and use the electrical methods and techniques to measure, manipulate, amplify, and control it.

One definition states[1] "A transducer is a device which, when actuated by energy in one transmission system, supplies energy in the same form or another form to second transmission system". The energy transmission may be electrical, mechanical, chemical, optical (radiant), or thermal.

A unit or the device which converts one form of energy into another form of energy is known as the transducer. In our case it means the conversion of sound energy into electrical one.

There are two familiar types of the transducer as far as the sound wave is concerned.

i. Microphone and, ii. Pickup

The microphones are universally used for vocal music as well as for the instrumental music, but pickups are used only for the instrumental music.

Microphones

The most common type of the transducer is the microphone nicknamed mic or mike. A microphone[2] is an electroacoustic transducer actuated by energy in an acoustic system and delivering energy to an electrical system, the wave form in the electrical system being substantially equivalent to that in the acoustic system.

Microphones are used in many applications such as

telephones, hearing aids, public address systems for concert halls and public events, live and recorded audio engineering, sound recording, two-way radios, radio and television broadcasting, and in computers for recording voice, speech recognition, and for non-acoustic purposes such as ultrasonic sensors or knock sensors.

Use of type of microphone depend on its application and preciseness required in to that.

All microphone work[3] on the general basic principle that the energy of the sound wave is converted firstly into mechanical energy and then into electrical energy. So they all need a diaphragm which will vibrate when the sound wave produces a difference of pressure between its faces, and some means whereby mechanical movement can cause electrical signals to be generated. It is interesting to note that this is opposite to the action of a loudspeaker, where electrical energy is fed in to produce the mechanical vibrations which cause sound waves to be set up in the air. The microphone is an example of an electrical generator, while the loud speaker is an example of an electrical motor.

Types of Microphone

Microphones are categorized by their transducer principle, such as condenser, dynamic, etc., and by their directional characteristics. Sometimes other characteristics such as diaphragm size, intended use or orientation of the principal sound input to the principal axis (end - or side-address) of the microphone are used to describe the microphone.

Several different types of microphone[4] are in use, which employ different methods to convert the air pressure variations of a sound wave to an electrical signal.

The most common are:

The carbon microphone : Also known as a carbon button microphone, uses a capsule or button containing carbon granules pressed between two metal plates.

The dynamic microphone : which uses a coil of wire suspended in a magnetic field.

The condenser microphone : which uses the vibrating diaphragm as a capacitor plate.

The piezoelectric microphone : which uses a crystal of piezoelectric material.

Laser Microphone : This microphone is a device that uses a laser beam and smoke or vapor to detect soundvibrations in free air.

Fiber optic Microphone : A fiber optic microphone converts acoustic waves into electrical signals by sensing changes in light intensity, instead of sensing changes in capacitance or magnetic fields as with conventional microphones

Speakers as microphones : A loudspeaker, a transducer that turns an electrical signal into sound waves, is the functional opposite of a microphone. Microphones typically need to be connected to a preamplifier before the signal can be recorded or reproduced.

While selecting the type of the microphone following factors are considered.

- Use of Microphones is either Outdoor or in door
- Use for microphone is for the purpose of speech or music / intelligibility required.
- Directivity of microphone
- Sensitivity of microphone
- Impedance of microphone
- Placement of microphone for musical instruments
- The precision required in the output v/s costing of the microphone.

PICK UP[5]

A **pickup** device is a type of transducer (specifically a variable reluctance sensor) that captures or senses mechanical vibrations produced by musical instruments, particularly stringed instruments such as the sitar, electric guitar, electric bass guitar violin etc. and converts them to an electrical signal that is amplified using an instrument amplifier (such as preamp) to produce musical sounds through a loudspeaker in a speaker enclosure. Most electric guitars and electric basses use magnetic pickups. Sitar, acoustic guitars, upright basses and fiddles often use a piezoelectric pickup.

There are basically four principles used to convert sound into an alternating current, each with their pros and cons:

- A **Microphone** registers the vibrations of the air caused by the instrument. In general this technique guarantees a good sound quality, but with two limitations: feedback and crosstalk.
- **Contact pickups** register the vibrations of the instrument itself. They have the advantage of producing little feedback and no **crosstalk at all**. In spite of their lesser sound quality and low price,

contact pickups (and especially the piezoelectric pickup) have become the most popular transducer.

- **Magnetic pickups**. Magnetic pickups, as applied in electric guitars, register the vibrations of nickel or steel strings in a magnetic field. They have the, but in combination with a steel-string acoustic guitar the sound tends to be electric. This is why acoustic guitarists typically choose a piezoelectric pickup, built in microphone, or both.
- **Electrostatic pickups**. Another way is to use the changing capacitance between the string and a pickup plate. These electronic pickups produce much higher dynamics than conventional pickups, so the difference between a soft and a loud pick strike is more pronounced than with other types of pickups

An amplification system with two transducers combines the qualities of both. A combination of a microphone and a piezoelectric pickup typically produces better sound quality and less sensitivity to feedback, as compared to single transducers.

However, this is not always the case. A less frequently used combination is a piezoelectric and a magnetic pickup. This combination can work well for a solid sound with dynamics and expression.

Magnetic pickups

A magnetic pickup is made up of the magnetic material like permanent magnet with a core of material such as alnico or ferrite, wrapped with a coil of several thousand turns of fine enamelled copper wire. The pickup is most often mounted on the body of the instrument, but can be attached to the bridge, neck or pick guard, as on many electro-acoustic archtop jazz guitars. Magnetic pickups used with string basses can be attached to the bridge. The permanent magnet creates a magnetic field; the motion of the vibrating steel strings disturbs the field, changing magnetic flux and inducing an electric current through the coil. The pickup is then connected with a patch cable to an amplifier which amplifies the signal to a sufficient magnitude of power to drive a loudspeaker. A pickup can also be connected to recording equipment via a patch cable. There may also be an internal preamplifier device mounted in an acoustic guitar or in an external box. When a preamp is used in this way, it is between the pickup and cable and can significantly reduce the equivalent impedance of the pickup coil.

Output

The output voltage of magnetic pickups varies between 100 mV r.m.s to over 1 V r.m.s for some of the higher output types. Some high-output pickups achieve this by employing very strong magnets, thus creating more flux and thereby more output. This can be detrimental to the final sound because the magnet's pull on the strings can cause problems with intonation as well as damp the strings and reduce sustain. Other high-output pickups have more turns of wire to increase the voltage generated by the string's movement. However, this also increases the pickup's output resistance/impedance, which can affect high frequencies if the pickup is not isolated by a buffer amplifier or a DI unit.

The turns of wire in proximity to each other have an equivalent self-capacitance that, when added to any cable capacitance present, resonates with the inductance of the winding. This resonance can accentuate certain frequencies, giving the pickup a characteristic tonal quality. The more turns of wire in the winding, the higher the output voltage but the lower this resonance frequency. The inductive source impedance inherent in this type of transducer makes it less linear than other forms of pickups, such as piezo-electric or optical. The tonal quality produced by this nonlinearity is, however, subject to taste, and some string instrumentalist and luthiers consider it aesthetically superior to a more linear transducer.

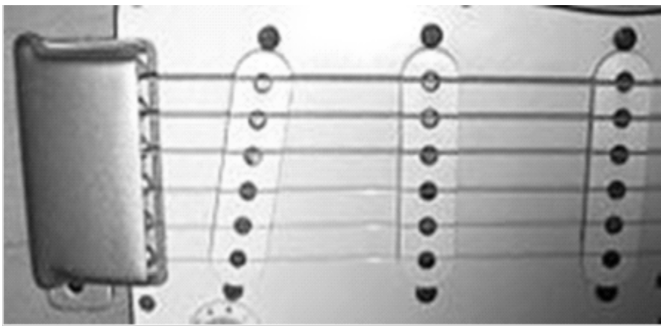

Fig. 1.1 Single coil pickups, Fender Stratocaster (1963)

The external load usually consists of resistance (the volume and one potentiometer in the string instrument, and any resistance to ground at the amplifier input) and capacitance between the hot lead and shield in the connecting cable. The electric cable also has a capacitance, which can be a significant portion of the overall system capacitance. This arrangement of passive components forms a resistively-

damped second-order low-pass filter. Pickups are usually designed to feed a high input impedance, typically a Megohm or more, and a low impedance load reduces the high-frequency response of the pickup because of the filtering effect of the inductance

This can create a whistling effect which is commonly seen in local pick up.

Piezo electric pick up

If certain materials are mechanically deformed, i.e. bent or twisted, a difference of voltage is produced between the faces of the material. This is known as the piezo electric effect[6] and is obviously applicable to the microphones and pickups since we can use the forces due to a sound wave or vibrations to drive a thin layer of suitable material. Although there are several possible materials, the one normally used is Rochelle salt since this is very sensitive and produces a good output signal

Sometimes string instrument player fit piezoelectric pickups instead of, or in addition to, magnetic pickups. These have a very different sound, and also have the advantage of not picking up any other magnetic fields, such as mains hum and feedback from monitoring loops. In hybrid guitars, this system allows switching between magnetic pickup and piezo sounds, or simultaneously blending the output. Solid bodied guitars with only a piezo pickup are known as silent guitars, which are usually used for practicing by acoustic guitarists. Piezo pickups can also be built into electric guitar bridges for conversion of existing instruments.

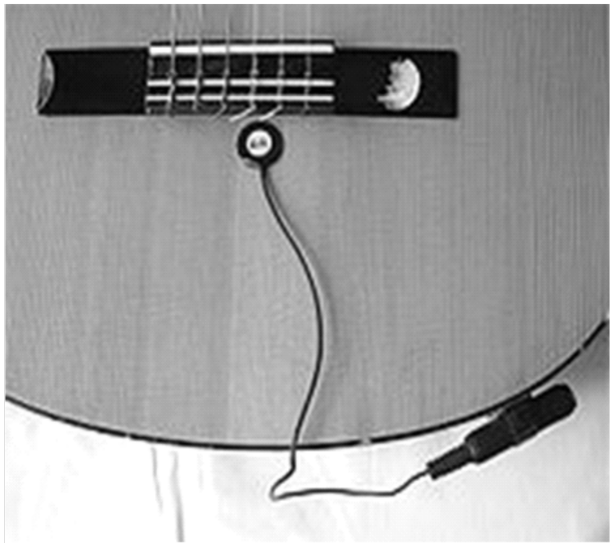

Fig. 1.2 Piezoelectric pickup on a classical acoustic guitar

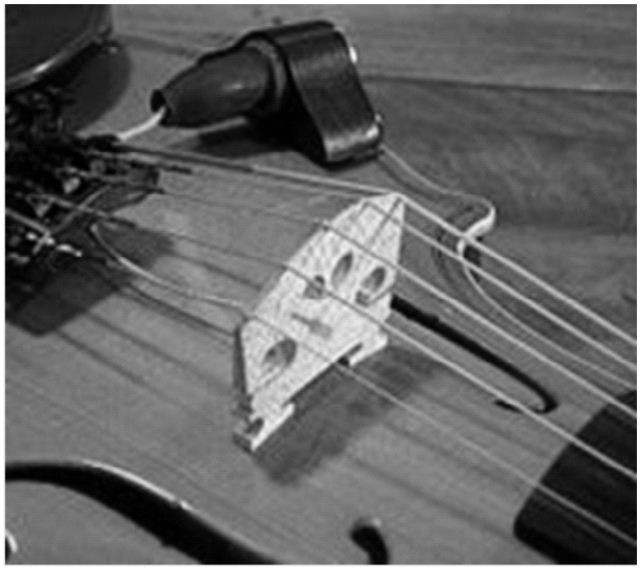

Fig 1.3 Piezoelectric violin bridge pickup

Most pickups for bowed string instruments, such as violin, and double is piezoelectric. These may be inlaid into the bridge, laid between the bridge feet and the top of the instrument, or, less frequently, wedged under a wing of the bridge. Some pickups are fastened to the top of the instrument with removable special putty usually of the black colour.

This putty is also carrying special characteristics of passing the vibrations on the surface to the transducer. Putty can not be replaced by ordinary glue or other sticky material.

Fig 1.4 Dual pickup by Peterman in Australia

The piezo pickup gives a very wide frequency range output compared to the magnetic types and can give large amplitude signals from the strings.

• Preamps

Piezoelectric pickups have a very high output impedance and appear as a capacitance in series with a voltage source. They therefore often have an instrument-mounted buffer amplifier fitted to maximize frequency response. The buffer amplifier is often powered from relatively high voltage rails (about ±9 V) to avoid distortion due to clipping. A less linear preamp (like a single-FET amplifier) might be preferable due to softer clipping characteristics. Such an amplifier starts to distort sooner, which makes the distortion less "buzzy" and less audible than a more linear, but less forgiving op-amp However, at least one study indicates that most people cannot tell the difference between FET and op-amp circuits in blind listening comparisons of electric instrument preamps, which correlates with results of formal studies of other types of audio devices. Sometimes, piezoelectric pickups are used in conjunction with magnetic types to give a wider range of available sounds.

Optical Pickup[7]

Optical pickups are a fairly recent development that work by sensing the interruption of a light beam by a vibrating string. The light source is usually an LED, and the detector is a photodiode or phototransistor. These pickups are completely resistant to magnetic or electric interference and also have a very broad and flat frequency response, unlike magnetic pickups. Optical pickup guitars were first shown at the 1969 NAMM in Chicago, by Ron Hoag

In 2000, Christopher Willcox, founder of LightWave Systems, unveiled a new beta technology for an optical pickup system using infrared light. In May 2001, LightWave Systems released their second generation pickup, dubbed the "S2." The S2 featured LightWave Systems' monolithic bridge, six-channel motherboard, and a host of other improvements, making the technology more practical for use in both live and recording studio settings.

Multi-transducer pickups[8]

This type of the pickups are not used by artists, except some professionals. Sometimes this single pickup contains sub six pickups. So it is called Hexaphonic pickup. Hexaphonic pickups also called divided pickups and polyphonic pickups have a separate output for each string (Hexaphonic assumes six strings). This allows for separate processing and amplification for each string. It also allows a converter to sense the pitch coming from individual string signals for producing note commands, typically according to the MIDI (musical instrument digital interface) protocol. A hexaphonic pickup and a converter are usually components of a guitar/synthesizer. Such pickups are uncommon (compared to normal ones), and only a few notable models exist, like the piezoelectric pickups on the Moog Guitar. Hexaphonic pickups can be either magnetic or piezoelectric or based on the condensor principle like electronic pickups.

Fig. 1.5 EMG 81 and EMG 85 pair of popular active pickups

Active and passive pickups[9]

Pickups can be either active or passive. Pickups, apart from optical types, are inherently passive transducers. "Active" pickups incorporate electronic circuitry to modify the signal. "Passive" pickups are usually wire wound around a magnet, and are the most common type used. They can generate electric potential without need for external power, though their output is relatively low, and the harmonic content of output depends greatly on the winding.

Fig.1.6 Seymour Duncan AHB-1 Blackouts

Active pickups utilize the same type of reluctance sensor as a passive pickup (although features such as coil wire size and number of windings may vary from those used in a passive pickup). Active pickups require an electrical source of energy (usually one or two 9V batteries) to operate and include an electronic preamp very similar to the preamp or buffer found in most amplifiers and effects circuits. These circuits can be designed to give a large range of gain for a large range of possible output power. The circuitry is virtually identical to any preamplifier or buffer found in amplifiers and effects circuits. Unlike the preamp of an amplifier circuit, the Op Amps used need to be of a low power design to optimize battery life and they are unable to utilize a Rail to Rail input power configuration due to the low battery power. This limits the dynamic range of the circuit when compared to a Rail to Rail Op Amp preamp circuit as found in most amplifiers. By adding an additional preamplifier/buffer active pickups are able to filter attenuate or boost the signal from the pickup. Any extra voltage gain added to the output signal will increase clipping and distortion in any subsequent part of the amplification chain. This additional distortion makes active pickups popular among metal and rock guitarists.

The main disadvantages of an active pickup system are that the system requires a battery power source to operate the active circuitry. Batteries limit the circuit design and functionality, in addition to being an inconvenience to the musician. The string instrument with active pickups may contain audio filters, which reduce the dynamic range and mildly distort certain ranges. High output active pickup systems also have an effect on an amplifiers input circuit. This is all to taste. However, when comparing circuitry with an oscilloscope or signal analyser, every aspect of a buffer or preamplifier circuit can be improved by a design that incorporates a rail to rail dual voltage supply preamplifier as found in most amplifiers. These can be designed with the same desired gain and filtration applied.

Stereo and multiple pickups with individual outputs

This is not a common type of the pickup which is used by sitar player, but some other string instrument players like guitar players are using this.

Rickenbacker was the first manufacturer who began producing stereo bass guitars with a stereo output for each pickup section. The neck pickup had one output and the bridge pickup had one. Also Teisco produced a guitar with a stereo option. Teisco divided the two sections in the upper three strings and the lower three strings for each individual output. The Gittler guitar was an experimental guitar with six pickups, one for each string. The Go Team has modified a Fender Telecaster with an additional rotated pickup for the upper string, causing a simulation of a one string bass sound. Gibson also created the HD.6X Pro guitar with The Hex Pickup that captures a separate signal for each individual string and sends it to the onboard analog/digital converter, which uses Gibson's digital transport technology to send the signal out of the guitar via Cat 5 Ethernet Cable. The output can be routed as a single summed mono signal to an amplifier or recording console. It can also send the E, A, and D strings to one amp or recording channel and the G, B, and high E to a separate amp or channel. Or it can send the output of all six individual strings to six different amps or channels. These six individualized outputs can used to create various effects.

Merits of using pickup over microphone for string instruments.

- In any kind of the microphone after generation, the sound wave first passes through the air and then enters the mic and processes further. At this stage some outside interference or unwanted noise also enters in to Mic along with desired sound (which is known as the cross talk) and also processes further.
- When we use mic as a transducer for amplification of sitar sound, its placement position is important .After putting it on proper position sitarist has to be in that position, while in case of pick up once it is fixed sitarist can take any position of sitting and play sitar without worrying about sitting position.
- Use of pickup offers better feedback and hence the manageability of the quality of the sound.More over to that sound reproduced at the other end using pickup transducer is capable of retaining original tonal quality of the sitar because of the capacity of covering the desired range of sound frequency.

Conclusion :

Thus the use of the pickup gives better feedback and avoids cross talk, covers whole desired frequency range of the string instruments, generating natural tone at the output end. So it is preferred to use pickup than microphone as a transducer for amplification purpose for the sound of string instruments.

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