COMB NOTCH FILTERING

INTRODUCTION

Interference in a testing environment comes in many shapes and sizes, almost equal in permutations to the number of BNC cables in the universe. In general, most interference sources come in one of two species; 1) those which are random in nature, or at least their appearance is unpredictable, and 2) those which regularly occur and their source is apparent. Often, attempts are made to eliminate interference by the classical "brute-force" approach, a Ouija Board and a Divining Rod. This may still be the only approach for random type interference, but a new tool has become available for some common types of interference; those which are rich in harmonics of a base frequency, such as AC power line interference.

A POWERFUL EXAMPLE

AC power lines are a prime source of interference in sensitive measurement setups. The fundamental line frequency, commonly 50, 60 or 400 Hz, is normally a large component, but one which can be dealt with by using a simple notch filter. However, in practice, because of the large preponderance of nonlinear loads on power systems, such as fluorescent lights, SCR's, rectifiers, etc., power lines are usually very rich in harmonic content. Since stray pickup is many times capacitive, the higher harmonics are emphasized and can become more significant than the fundamental. In a typical 60 Hz system, harmonics up to and beyond 10 kHz (167 harmonics) are commonly encountered. Attempting to eliminate such interference by classical filtering is impractical and a fresh approach to this problem is discussed below.

A SPIKY SOLUTION

An ideal solution to the problem of AC power line related interference is to place a notch filter at each harmonic of the line frequency. In order to effectively eliminate the interference, yet not eliminate desired signal responses, each notch should not only be very deep but also as narrow as possible. Deep, narrow notches require precise frequency control to keep the interference squarely centered in the notch. These demands can not be realized effectively by using the classical filtering approaches (active or passive).

A manufacturer (See Xetron ad on page 145) has recently developed a family of comb notch filters specifically addressed to this problem. The LINX filters (LINX is an acronyin for line interference network.) are digital filters, and as such, are able to provide selectivity and performance heretofore unobtainable:

- Narrow (0.5 Hz, 3dB bandwidth,
- Deep (-55 dB) notches
- Precise frequency control (digital synthesizer); no drift or temperature instability
- Non-critical design; no "tweaking" or alignment required.

These filters provide up to 200 simultaneous notches, one at each harmonic of the line, with identical selectivity characteristics. The 3dB bandwidth of the notches is switch controllable from approximately 0.5 to 6 Hz. The overall passband is typically DC to 10kHz.

The center frequency range of each filter is quite broad, normally covering up to one octave. For example, a filter designed for 60 Hz application would operate anywhere in the region of 40 to 80 Hz. Since the center frequency is synthesizer controlled, no adjustments are necessary for fully automatic operation anywhere within this range.

An outstanding feature of the LINX is the flexibility of the reference generator, which controls the center frequency of the notches. A front panel switch selects one of three options for the reference source:

1) **Power Line:** derived directly from local AC line powering the LINX
2) **Extraction:** a front panel operated tunable filter extracts a reference signal directly from the input signal.
3) **External:** for locking to remote power line or other external source.

An important point to emphasize is that the LINX, although locked to the reference frequency, is not sensitive to the reference phase angle. Thus, the phase of the reference source need not be controlled nor be related to the phase of the interference signals. Therefore differences in phase, which are common in power distribution systems, have no effect on proper operation of the filter.

The above article was prepared by Robert Metzner, Xetron Corp. Reprinted by permission.

A DRAMATIC ILLUSTRATION

A very dramatic illustration of the effectiveness of the LINX is common to everyone's experience. Touching the "hot" lead on a high impedance microphone with one's finger normally creates such a severe interference problem that any desired signal is completely masked by the resultant noise. Spectrographic analysis of this interference will usually show that it is composed almost entirely of harmonics of the local power line, extending throughout the audio band. Higher harmonics are often present to a much greater degree than would be suspected, because the capacitive nature of the coupling to the line greatly increases the pickup of the higher harmonics. Use of a LINX in this situation would result in complete elimination of all interference, and restoration of the desired audio pickup.

Although this is an extreme example, situations often arise where shielding is inadequate; such as laboratory experiments, field tests, or any number of instances where audio or transducer data signals are covered up by interference. If the source of interference is not line-related, but instead related to some other event such as a DC motor or other rotating machinery, it is often possible to derive a reference input for the LINX-60L directly from the interference souce itself.

SOME TYPICAL APPLICATIONS

In addition its obvious application to EMI testing, other uses are apparent for the digital comb notch filter:

TRANSDUCER PICKUP Low level transducers, such as microphones or instrumentation sensors are especially susceptible to power line related interference pickup because of their low operating level. Ground loops, inadequate shielding, and long cable runs are a few of the problems frequently encountered. Brute force solutions are sometimes haphazard and usually time consuming, considering the multiple interference paths possible. Regardless of the source or multiplicity of sources of power line related interference, the LINX will eliminate the interference. Its use is particularly advantageous for quick lash-ups or temporary installations when time or circumstances make it impractical to carefully shield and properly ground all sensitive paths. Although not recommended, it is even possible to do away with any shielding of low level lines altogether, since the LINX will effectively remove interference which is completely masking a small desired signal.

RECORD INTERFERENCE Power line related interference in a recording is effectively removed by the LINX using the internal extraction filter. Due to the erratic characteristics of recording apparatus, the interference frequencies will be unstable because of speed inaccuracies, wow, and flutter. In the extracting mode, the reference signal is obtained from the interfering signal contained in the audio input itself. Thus, the LINX-60L locks onto and tracks any varying interference signal.

COMMUNICATIONS RECEIVER INTERFERENCE RF radiation from power lines, especially high tension lines, flourescent lights, SCR controllers, etc., can be a very serious problem. This is particularly the case in the HF band when the receiver is located near an industrialized urban area. Such man made noise very often contains large spurious components which are harmonically related to the power line frequency. This is because the power line, acting on non-linear loads, such as SCR controllers, can generate only harmonics of itself which extend well into the RF region. Normally, no other unrelated frequencies are generated, except by parametric means. A radio receiver can receive and demodulate this RF interference, and through intermodulation distortion, or other means, generate audio output products which are harmonically related to the power line frequency. The LINX, connected between the receiver output and the speaker or headphones, can effectively eliminate this interference problem. If the source of interference is local, the power line may be used as a convenient reference. If the interference source is remote, the reference may be extracted directly from the receiver output itself.

NON-POWER LINE RELATED INTERFERENCE The LINX is also useful for eliminating certain types of interference not related to the power line. Rotating machinery, conveyor belts, chain drives, etc., sometimes generate electrical noise and induced emf's due to their motion. If the noise is of a periodic nature, albeit rich in harmonic content, the LINX can eliminate such noise if a proper reference is applied. The reference can normally be obtained from a tachometer or other device coupled to the machine whose output is somehow related to the noise repitition rate. The periodic noise and all of its harmonics can thus be removed from nearby transducers.