

# 1/f NOISE STUDIES IN CERTAIN PHYSICAL SYSTEMS

## GENERAL SUMMARY

The study of noise is perhaps the most selective field. Starting right from the observation of "Brownian Motion" in pollen grains it has been an interesting field of study. It was later shown by Einstein that Brownian motion to be due to the incessant and random bombardment of the molecules of the surrounding liquid, and such fluctuations are now referred to as "noise". It has become a common practice to call the fluctuating component of any measurable quantity as noise.

The 1/f noise and burst noise are both low frequency noise phenomena. 1/f noise phenomenon was first studied as an excess low frequency noise in vacuum tubes, in semiconductor devices. Since the mid-fifties, it has been observed as fluctuations in the parameters of many systems. Many are totally unrelated to the devices themselves and their 1/f noise cannot be explained by any of the models developed for these devices. Chapter 1 deals with introductory aspects of 1/f Noise.

The features of 1/f noise phenomenon are highly striking. One is its uniqueness and two is its noise spectrum. The 1/f noise spectrum has the same form characteristic in systems as diverse as those mentioned above. These features suggest that there must be some universal mechanism. However it has not been possible to establish such a universal noise mechanism. Moreover the second feature of 1/f noise is mathematical rather physical. In the past, 1/f noise has been variously called as current noise, excess noise, flicker noise (thermionic emission), semiconductor noise, and contact noise. All these names have been dropped recently and only the name 1/f noise has been retained.

Low frequency fluctuations showing a power spectral density inversely proportional to the frequency are observed in various physical, technical, biological and economic systems. This peculiar phenomenon which is called 1/f noise or flicker noise has stimulated the research efforts of numerous scientists. The important conclusions of the 1/f Noise studies are:

1. The shape of the power spectral density is of the  $f^{-1}$  type with lying between 0.8 and 1.4. This spectral shape has been observed over a wide range of frequencies from  $10^6$  Hz to  $10^6$  Hz or higher.

2. The amplitude distribution of  $1/f$  noise is strongly Gaussian. Although considerable deviations from a Gaussian distributions have been observed, they are attributed to interference effects with additional low frequency noise components particularly burst noise. Handel's theory of  $1/f$  noise is also called as the quantum  $1/f$  noise theory. This theory is the culmination of a series of efforts to develop a fundamental and universal theory of  $1/f$  noise by Handel and co-workers since. Chapter 2 presents theoretical basis for  $1/f$  Noise. In chapter 3 more sophisticated studies in homogeneous semiconductors have been investigated (as presented by Hooge). Chapter 4 deals with the so called quantum  $1/f$  Noise theory as improved by van Vliet.

Chapter 5 describes the tools that are to be adopted for digital signal processing. The need for DSP and the advantages of DFT and FFT are dealt in detail. The theoretical basis of DFT and FFT and the exact advantages of adopting these techniques are dealt. Algorithms required to adopt DFT and FFT are detailed in Chapter.

Chapter 6 deals with the experimental methods adopted in the present work. The present study is confined to the broad methods adopted required for  $1/f$  studies. The requirement of special biasing circuits, broad band amplifiers, FFT software and other software (& hardware requirements) are discussed. The MATLAB software has been extensively used to build programs for the DSP requirements and to meet the requirement for sophisticated analysis.  $1/f$  Noise measurements are performed on 1) n-channel MOSFETS (consumer electronics type) 2) JFETs 3) Resistors 4) Ferrite Composites, 5) thermistor and 5) sound and music.

The conclusions that are arrived in the present study are one single  $1/f$  noise source is attributed in Ferrite Composites, Resistors (both carbon & metallic) and thermistor. The  $1/f$  noise output in JFET is ideal while that at lower voltage is slightly deviated. In all types of speech and musics studied the  $1/f$  noise relation holds good.

The present study is to examine the MOSFETs extensively for  $1/f$  noise output under their linear operation. It has been found that IRF 540 shows almost ideal  $1/f$  behaviour at least at lower  $V_d$  values indicating that there exist more isolated traps in these devices. MOSFET IRF 840 also shows near  $1/f$  noise at lower  $V_g$  biasing. IRF 830 and IRF 740 have definite deviation from the  $1/f$  line indicating that these do not contain isolated traps as required for ideal  $1/f$  behaviour. At higher frequencies the  $1/f$  line tends to become parallel in the case of IRF 740 and IRF 830. This indicates that that may be two (or more) sources that give rise to different Lorentzians. As demonstrated in the discussion part presence of two Lorentzians would lead to this type of behaviour. This also stress the need to extend the higher frequency region to exactly point out whether the noise settles down to  $1/f$  behaviour. It is hoped that our school would investigate in these lines in our future programs.