Wide-Band GaAs MMIC Low-Pass Filters

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ABSTRACT

Very small, Wide-band and low loss GaAs MMIC Bessel-Thomson, Gaussian and dissipative low-pass filters are proposed as low signal distortion filtering elements suitable for inclusion into high-speed fiber optic receivers.
Five-element 2.5, 5 and 10 Gb/s filters using lumped reactive elements have been designed and fabricated using a standard MMIC foundry process.

INTRODUCTION

Traditionnal transmission-line or lumped-element low-pass filters using off-the-shelf capacitors and inductors have been used as filtering elements in low-to-medium speed fiber optic receivers. However, due to the emergence of the Synchronous Optical Network standard (SONET), new strict limits are now placed on the shape of the receiver eye diagram [1]. As an important cause of eye distortion may come from the overall pulse filtering process, a precise and reproducible frequency response is needed [2]. In this paper, low-signal distortion five-pole GaAs Bessel-Thompson, Gaussian and dissipative low-pass filters are described.

A. BESSEL-THOMPSON LOW-PASS FILTERS

Bessel-Thompson or linear phase filters present the shortest rise time and show no overshoot when compared with Chebyshev or Butterworth filters [3]. In that sense, these filters may be considered as the best choice for Non Return to Zero (NRZ) signal filtering. The reactive elements values of the prototype low-pass filter shown in Fig. 1 are computed from a maximally linear phase approximation as follows [4] :

$G1 = 0.3932$ (1)
$G2 = 0.6954$ (2)
$G3 = 2.5640$ (3)
$G4 = 0.9203$ (4)
$G5 = 0.2743$ (5)
$Ci = Gi/(R0.2.pi.BW)$ (6)
$Lj = Gj.(R0.2.pi.BW)$ (7)
BW = - 3 dB bandwidth
R0 = load resistance

The layout and the measured 10 Gb/s eye diagram of a dual 7.5 GHz bandwidth, 5-element Bessel-Thompson low-pass filter are shown in Fig. 2.

B. GAUSSIAN LOW-PASS FILTERS

Gaussian filters exhibit an $\exp(-k.f^2)$ magnitude frequency response. In that sense, these filters may be considered as the best choice for filtering gaussian-like pulses such as solitons [5] because the filtering effect is mainly an increase of the pulse width without any overshoot. The reactive element values of the prototype low-pass filter shown in Fig. 1 are obtained after a Gaussian approximation of the transfer function :

$G1 = 0.2568$ (8)
$G2 = 0.8493$ (9)
$G3 = 2.5144$ (10)
$G4 = 0.5769$ (11)
$G5 = 0.3174$ (12)
BW = - 3 dB bandwidth
RO = load resistance

The layout of a quad 5-element Gaussian low-pass filter is shown in Fig. 3. To account for early bandwidth limiting effects due to non-ideal preceeding photodetector and amplifiers, the filter -3 dB bandwidth may be selected from 6.4 up to 8.4 GHz by wire-bonding a single filter among four.

C. DISSIPATIVE LOW-PASS FILTERS

Purely reactive filters depend on reflection for their transmission performance. When termination impedances are poorly controlled, reflection filters may produce in-band pulse distortions. In addition, stop-band energy is reflected back to the source and this may be undesirable in some cases.
Dissipative filters, on the other hand, achieve filtering action by absorption and present a good impedance match both in-band and out-of-band. A prototype of a constant-delay dissipative low-pass filter using 1-pole bridged-tee cells is shown in Fig. 4. A bridged-tee delay equalizer was added at one filter end to compensate for the filter delay distortion thus producing a flat total delay in the pass-band. This filter may be designed after the following equations :

$W1 = 2.pi.\ BW/sqrt(2\wedge(1/N)-1$ (13)
$L = R0/W1$ (14)
$C = 1/R0/W1$ (15)
$W2 = W1.(4/N)\wedge(1/3)$ (16)
$C1 = 1/2/R0/W2$ (17)
$C2 = 2/R0/W2$ (18)
$L1 = R0/W2$ (19)
N = number of resistive cells
BW= - 3 dB bandwidth
R0 = load resistances

D. CONCLUSION

Wide-band 5-pole Bessel-Thompson, Gaussian and dissipative low-pass filters have been designed and fabricated using a standard GaAs MMIC foundry process [6]. Synthesis formulas have been given, thus easing the design process of these filters. Applications of these integrated circuits include SONET receiver testing, measuring equipment and high speed NRZ or soliton fiber optic receivers.

E. ACKNOWLEDGEMENTS

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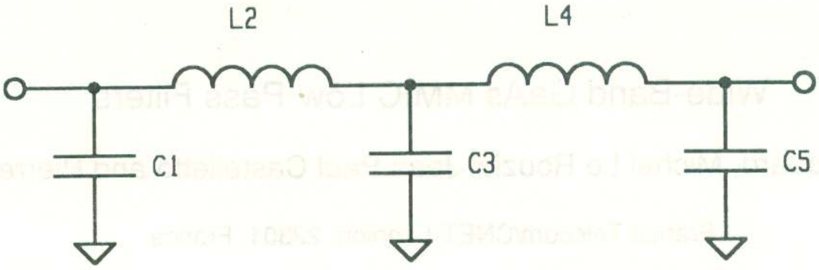
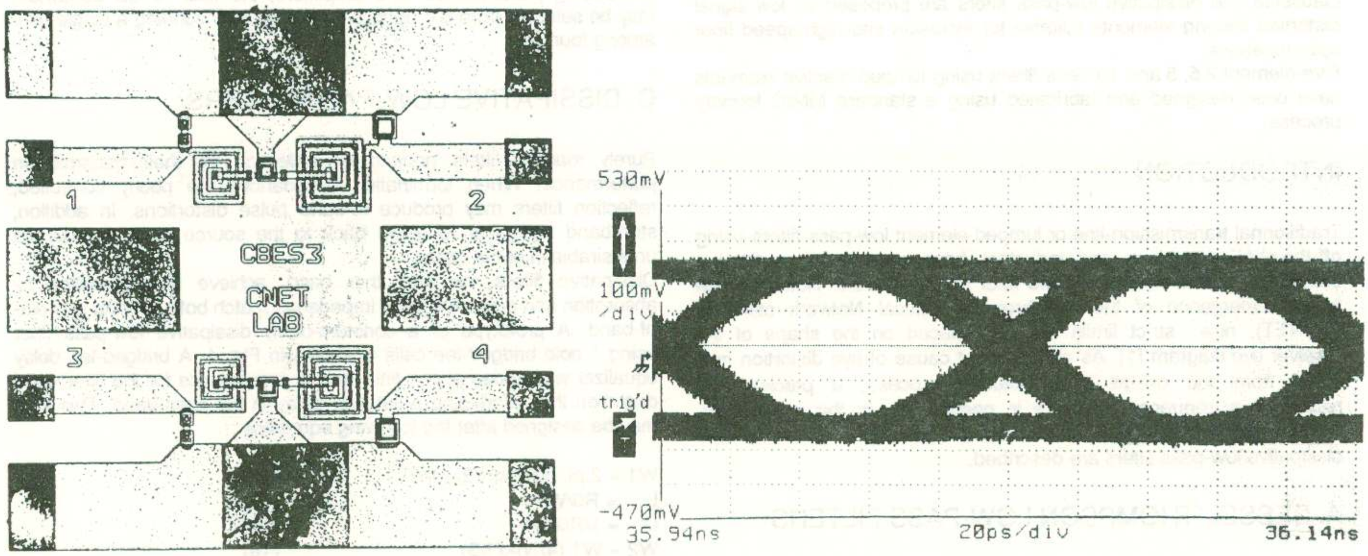


Fig. 1: low-pass filter prototype



(a) photograph

(b) 10 Gb/s eye diagram

Fig.2: dual 7.5 GHz bandwidth Bessel-Thompson low-pass filter

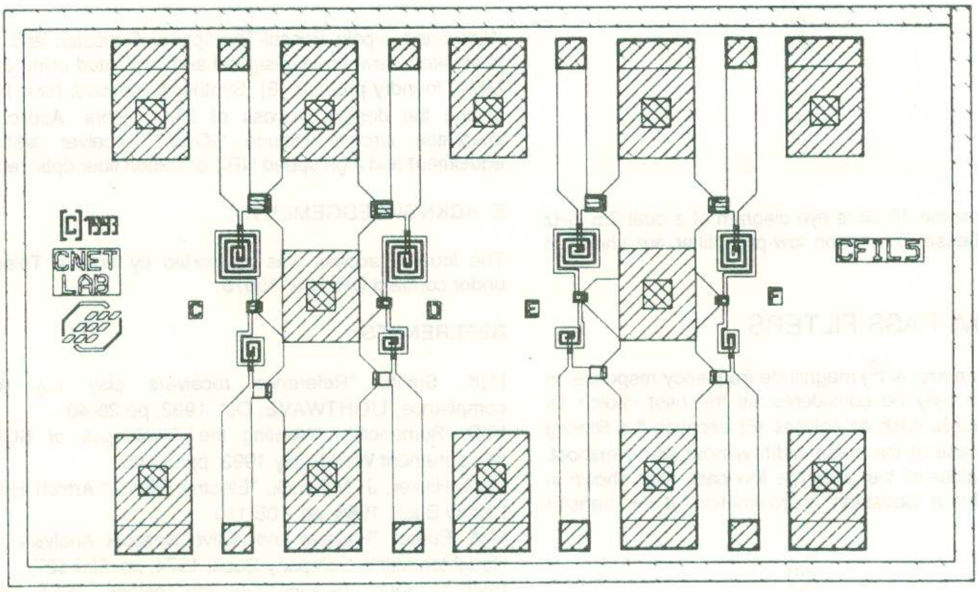
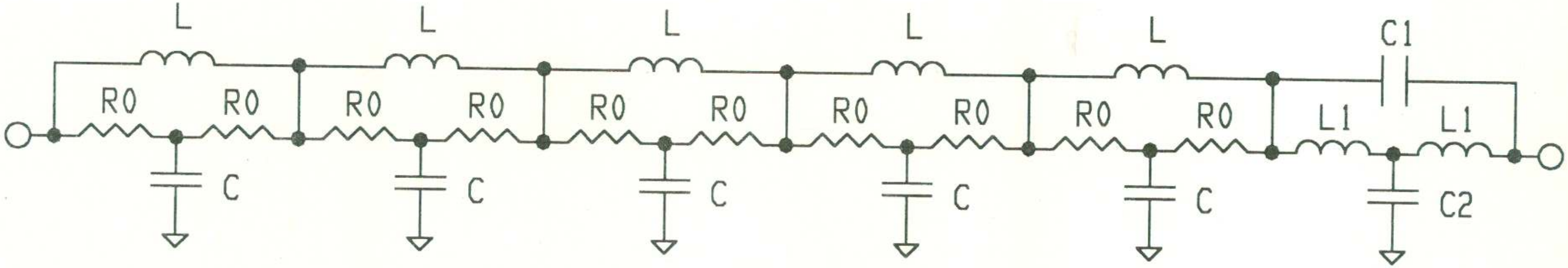
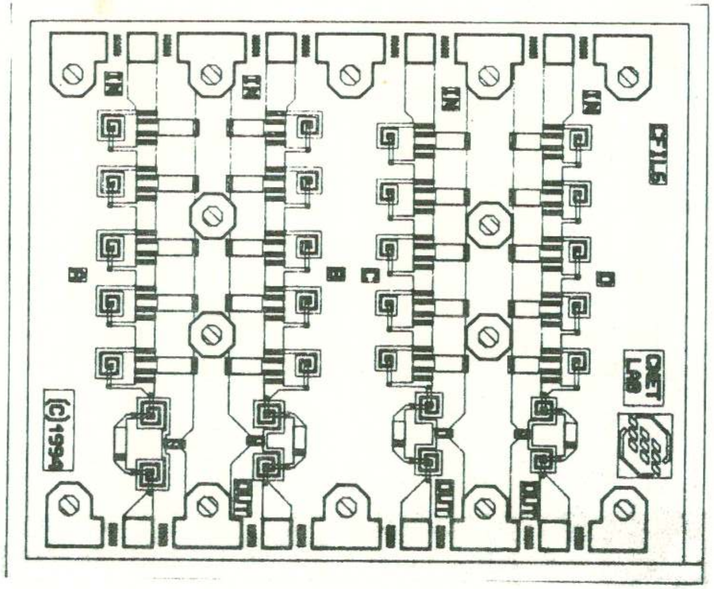


Fig.3: Quad Gaussian low-pass filter layout



(a) Schematic diagram



(b) MMIC layout

Fig.4: a 5-pole 10 GHz bandwidth dissipative filter