Fast Synchronous Detector Based on Video Switches

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***Abstract* - The highest operating frequencies of cost effective synchronous rectifiers are not exceeding 100kHz by error of 1%, in general. Lately introduced fast PIP video switches allow significantly increase the highest operating frequency. Based on the modern IC technology a synchronous detector module was built that has total gain error less than 0.05% up to 100kHz of switching frequency and less than 0.2% up to 1MHz frequency. The module can be used for AC signal measurements and impedance analyse due the built in source of excitation voltage. It can be controlled through a PC LPT interface.**

1 Introduction

Switching mode synchronous detection (SD), also known as synchronous rectification, is a cost effective method for phase sensitive AC and impedance measurements. Benefits of the technology are dynamic reserve up to 120dB, low part count and low price comparing with fully analogue multipliers or DSP based solutions. Simple SD modules can be used in battery powered bio-impedance meters for health condition monitoring of people, for signal processing of Doppler effect based sensors, ε measurement of materials, etc. Many applications require measurement accuracy of 1-5% in frequency range up to 10MHz. Most of the existing solutions do not allow achieving that high upper operating range. However, some technical possibilities already exist to solve the problem of building precise mixed type multipliers for frequencies of 10-50MHz.

2 Current mode signal multiplication

Switching losses cause the major error of switching type multiplication. The gain error ΔK depending on turn-on (t_{on}) and turn-off (t_{off}) times and signal period T can be calculated by Formula 1 [2]:

$$\Delta K = 1 - 1/2\left(\cos(\pi t_{on}/T) + \cos(\pi t_{off}/T)\right) \quad (1)$$

Recently there was no suitable switching IC available to perform switching for less than 1ns. For a long time discrete components gave the best switching characteristics. Appears that most significant source of switching delays by design of discrete components was driver circuitry as shown before [3]. To minimize required output swing of driver the current mode multiplication was the best approach. Current mode multiplication keeps the signal level close to zero and required control voltage is minimized. Also, the dynamic range of current mode multiplier is wider than by voltage mode multiplier. Author breadboarded some practical solutions of conventional current mode multipliers. Achieved results are shown on Figure 1, first two curves (current switches 1, 2) from left. Averager realised on operational amplifier followed the current mode multiplication unit in first case. As shown the achieved highest frequency was 300kHz @1% gain error in best case.

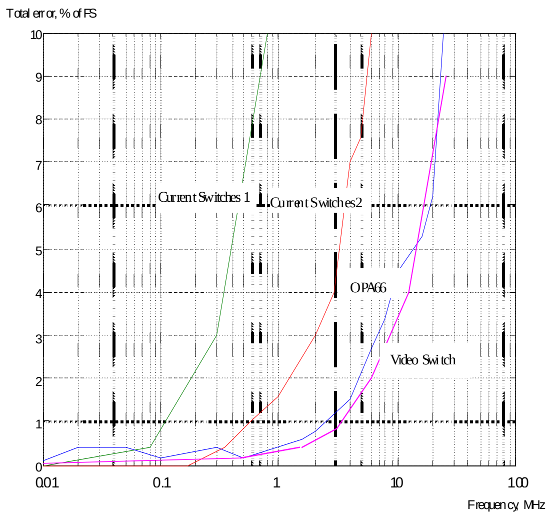


Figure 1: Errors of different SD multipliers

However, the results did not satisfy expectations and fully current mode solution was tested [4]. The averager was based on diamond transistor OPA660 [1]. Results are also shown on Figure 1, curve is marked by 'OPA660'. The significant disadvantage of circuitry was low accuracy in area of low frequencies as it can be seen.

3 Multiplier with video switches

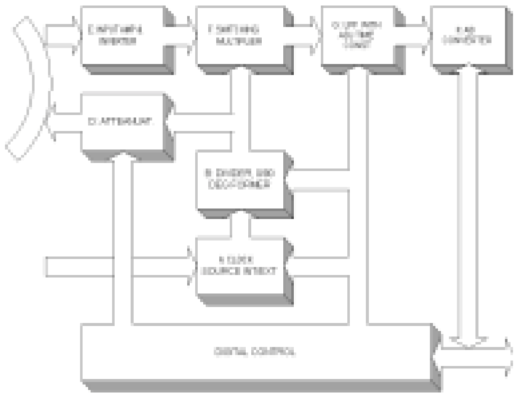
Lately fast analogue switches became available because of need of TV industry to perform RGB switching. The typical switching time is 1-2ns. Using that kind of devices with integrated driver it is easy to design circuitries of SD. First device tested was Elantec EL44332, which did not give good results because of internal architecture. The active averager on op amp was still required, which produced the main error of circuitries tested at first. The second prototyped solution was based on IC LT1675, which gave the best result comparing with previously tested solutions. The measuring results are again on the Figure 1, the most right curve. High frequency performance of multiplier was similar to results of

OTA-based scheme but the results in low frequency range were significantly better. The upper frequency range by gain error of 1% was 3MHz and 15MHz by gain error of 5%. The error was below 0.25% up to frequency 1MHz.

4 Complete design of SD module

According to achieved test results a synchronous detection module with video switches was designed. The block scheme of module is shown on Figure 2.

Figure 2: Block scheme of SD module



Module consists of following units: A – onboard clock generator 50MHz with additional input for external clock source (TTL), B - programmable clock divider and quadrature signal former, D – output attenuator of excitation signal, E - input signal amplifier, F - switching type multipliers for I and Q components, G – low pass filter with two selectable time constants, G – 12 bit serial AD-converter (60dB output dynamic).

The analogue path of schematic shown on Figure 3 was realized on MAX4108s high-speed amplifiers and LT1675 video switches.

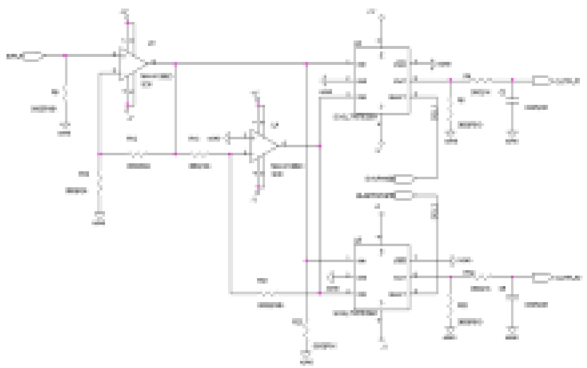


Figure 3: Analogue part of SD multiplier

Passive low pass filters follow multipliers, that solution gives best dynamic range as seen by experiments. AD converter sampling could be synchronised with excitation signal to minimize impact of white noise. The digital part of module consists of 50MHz clock source, 2^{30}-order clock signal divider, which allows achieving linear frequency step, and quadrature component former. Code former is realized on Xilinx XC95108 FPGA. Module could be controlled through conventional PC LPT port for highest convenience. Module requires just a single unstablilised input power source. All required voltages are generated internally. The hardware price of complete module can be estimated as $50, which is close to price of a single high-speed analogue multiplier IC. The actual look (2/3 of original size) of module is shown on Figure 4.

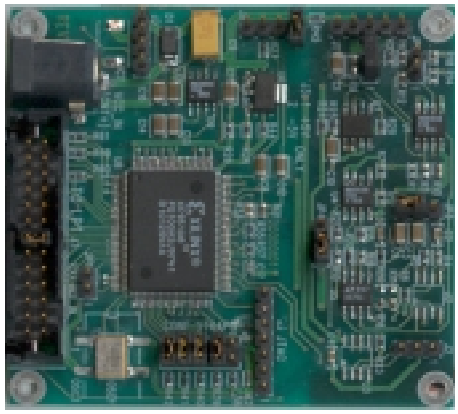


Figure 4: Outlook of simple SD module

5 Conclusions

Switching mode synchronous detection is a cheap HW solution if phase sensitive signal rectification is required. Design based on video RGB switches seems to be the best approach at moment to build devices with moderate accuracy of 1% in frequency range up to 10-20MHz. A sample detector module was built and tested by author. It is small, simple PC-driven and could be used for impedance measurements.

References

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