

HIGH SPEED 2-BIT ANALOGUE-DIGITAL CONVERTOR USING LiNbO_3 WAVEGUIDE MODULATORS

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A Ti-diffused LiNbO_3 waveguide optical circuit, whose element is a balanced bridge modulator, was fabricated for application in a 2-bit analogue-digital (AD) conversion system. Using this device with a $0.8 \mu\text{m}$ wavelength pulsed laser diode, up to 240 Msamples/s high bit rate AD conversion operations were successfully achieved.

The electro-optic analogue-digital (EO AD) convertor proposed by Taylor¹ has brought about the possibility of achieving giga-sampling AD conversion. Based on the EO AD convertor design,^{1,2} several fundamental experiments have been demonstrated.³⁻⁵ The first step for realising the EO AD convertor is to make a modulator array for obtaining multibit devices. In this case, the speed, driving voltage and optical losses become important factors for the AD convertor system performance. Up to the present, almost all devices reported have Y-branched and interferometric structures.

In this letter, up to 240 Msamples/s EO AD 2-bit conversion operations are presented, based on the development of an LiNbO_3 optical circuit, integrating for simplicity two modulators in array. The balanced bridge modulator⁶ is adopted as an element. Although the structure is rather complex, it has several advantages over the interferometric modulator. First, it has a lower propagation loss and a higher extinction ratio because it contains fewer branched and curved waveguides. Second, conversion error due to light source power fluctuation can be remedied by making full use of the two complementary optical outputs.¹

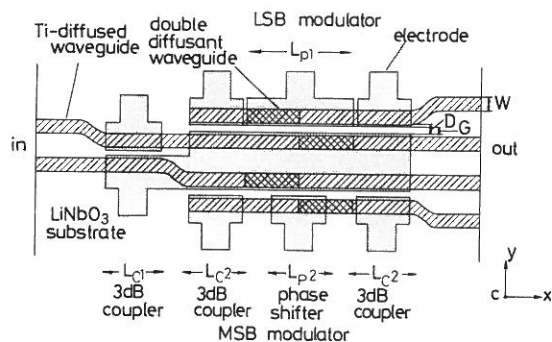


Fig. 1 Fabricated waveguide optical circuit configuration containing one 3 dB coupler and two balanced bridge modulators

Fig. 1 shows a configuration of the Ti-diffused LiNbO_3 waveguide integrated circuit for the AD convertor. The device is composed of one 3 dB directional coupler for light power dividing and two balanced bridge modulators. Each modulator is in turn composed of two 3 dB couplers and a phase shifter. To decouple light powers in the phase shifters, the Ti double diffusant method⁶ was applied.

The total device length is 29 mm, where the 3 dB couplers and phase shifters are 4 and 8 mm long, respectively. Electrodes for phase shifters are 8 mm long for the least significant bit (LSB) modulator and 4 mm for the most significant bit (MSB). Waveguide width W , spacing between waveguides G and electrode gap D are 4.6 , 6.2 and $5.5 \mu\text{m}$, respectively.

In the low frequency measurements with TM-like fundamental mode at $\lambda = 0.83 \mu\text{m}$ wavelength, half-wave voltages V_{π} were 3.1 and 5.8 V, and extinction ratios ER were 18.2 and 18.5 dB for LSB and MSB, respectively. Total insertion loss involving coupling and propagation loss was 9.9 dB. In this case, about 5 V DC bias was applied to the power dividing 3 dB coupler and 7–10 V DC biases to the other 3 dB couplers. No DC drift due to the buffer layer was observed. $V_{\pi,MSB}$ was then found to be not equal to $2V_{\pi,LSB}$. The main reason is probably the antisymmetric electrode configuration of the MSB phase shifter.

Using an experimental set-up as shown in Fig. 3 of Reference 1, high speed AD conversion experiments were carried out. Incident light from a pulse modulated GaAlAs

laser diode ($\lambda = 0.83 \mu\text{m}$) was fed into the optical circuit. Two light outputs (one from the MSB modulator and the other from the LSB) among the four, modulated by applied microwave (analogue) signals, were separately detected by two Si APDs. The outputs from the APDs were amplified and introduced into two electronic comparators having 1–2 ns rise and fall times. The microwave signals from the oscillator were amplified by a wideband power amplifier to have about 20 dBm and applied to the modulators.

AD conversion operations were examined as follows. Analogue sinusoidal signals $f_a = 10$ –60 MHz were applied to the phase shifter electrode, and synchronously, four times bit rate $f_s = 40$ –240 Msamples/s optical pulse trains were fed into the optical circuit for optically sampling the analogue signals. In all cases, reasonable and accurate conversion results were obtained. Fig. 2 shows an example of the operation for $f_a = 10$ MHz and $f_s = 40$ MHz.

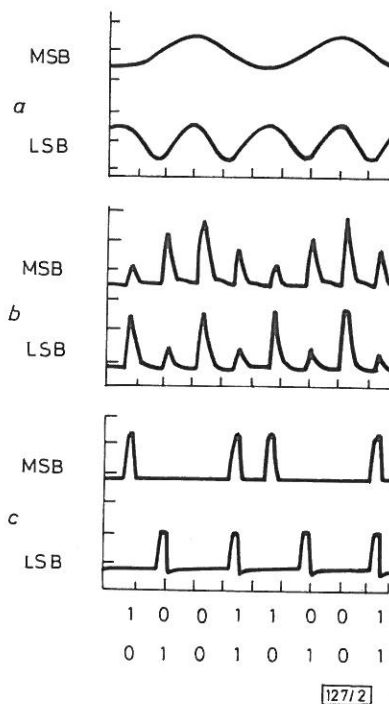


Fig. 2 Electro-optical AD conversion results for analogue signal $f_a = 10$ MHz and sampling speed $f_s = 40$ MHz

- a Outputs from Si APDs with CW light source
- b Outputs from APDs with pulsed light source
- c Comparator outputs indicating parallel two bit digital words 11/10/01/00 ...

Fig. 2a shows modulated outputs from the APDs when CW light was fed into the device. After adjusting the device into the Gray code configuration, the laser source was pulse modulated. The APD outputs in this case are shown in Fig. 2b. If the thresholds of the comparators are properly set to the inputs as shown in Fig. 2b, 2-bit parallel digital words, 11/10/01/00, are obtained in a period of analogue sinusoidal signals, as shown in Fig. 2c. Here the sampling bit rate was mainly limited by the response time of the electronic comparator, which is up-to-date ultrafast.

A Ti-diffused LiNbO_3 waveguide optical circuit, integrating one 3 dB coupler and two phase shifters, was fabricated for 2-bit ADC application. Using the device with a pulsed laser diode, up to 240 Msamples/s high bit rate AD conversion operations were confirmed. Based on the results, 4–6 bit AD conversion devices can be easily realised. More rapid conversion speed about 1–2 Gsamples/s could be achieved in the EO AD convertor, if the further improvement of the performances of the IC comparator occurs.

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