2.24 Gbit/s DIRECT MODULATION OF INJECTION LASER BY MONOLITHIC SILICON MULTIPLEXER

Berthold G. Bosch, Ulrich Langmann, and Detlef Daniel

Institut für Elektronik, Ruhr-Universität Bochum,

D-4630 Bochum, F. R. Germany

ABSTRACT

It is shown that direct laser-diode pulse-code modulation at 2.24 Gbit/s can be performed by a fast Si monolithic integrated bipolar circuit (2.5 µm design rules, pn-junction isolation, $f_T \approx 7$ GHz at $V_{CE} = 1$ V): The current switch output stage of a 4:1-time-division multiplexer IC feeds a modulation current swing of 4 mA into a TJS injection laser biased above threshold. The measured laser diode response for different static data input patterns are reported.

INTRODUCTION

In various laboratories work is being performed on realizing fiber-optic PCM communication systems with bit rates well into the Gbit/s range. Vital electronic circuits for such systems are time-division multiplexers (MUX) for serializing several contributing signals of lower data rate, cf (1).

In the past, multi-Gbit/s multiplexers were implemented as hybrid circuits, see e.g. (2). With the trend to monolithic solutions even at these high bit rates, GaAs seems to be particularly suited because of its well-known advantages as a material for fast circuits. Indeed, GaAs MUX implementations have been reported which could be operated up to 3 Gbit/s (3), 1.8 Gbit/s (4), and 0.6 Gbit/s (5).

It is the purpose of this contribution to show that one must not necessarily turn to GaAs solutions for realizing monolithic injection-laser MUX/driver circuits in the multi-Gbit/s range.

DESCRIPTION OF THE MUX CIRCUIT DRIVING THE LASER

For use in a planned wideband subscriber network operating at 1.12 Gbit/s (6), an ECL-compatible silicon bipolar 4:1-MUX IC was recently developed and implemented in our Institute at the Ruhr-Universität Bochum for the Heinrich-Hertz-Institut . The circuit is described in detail in (7); the features of its operation and its design guidelines may be summarized as follows:
As shown in Fig. 1 four current switches working on a common load are selected by series-gated select inputs S_0 and S_1. If two pulse trains of period T, shifted in phase by about T/4, are applied to S_0 and S_1, the data at the inputs D_1 to D_4 are selected cyclically and appear at the output in time slots of width T/4. Without resorting to a very sophisticated technology, the relatively high MUX bit rate was achieved by modifying conventional designs of commercially available multiplexers in some points. This included employing differential operation at reduced single-ended voltage swings and adding a buffer stage between the serializer and the output emitter followers. In addition, great emphasis was put on very careful circuit simulation and optimization.

By eliminating output emitter followers and by letting the current switch of the buffer stage drive the output load directly (Fig. 1), the bit rate could be raised to about 2 Gbit/s (7). A further increase in bit rate was achieved by reducing the dynamic output impedance of the reference voltage source for the upper current switches. To this end a 100 pF shunt capacitance C_1 was put across the internal reference (7); the same result can be achieved if, instead, the output resistance itself of the reference voltage source is lowered.

The MUX/driver IC was implemented in a bipolar technology using double implantation, 2.5 µm emitter stripe widths, pn-junction isolation, and two-layer metallization. The transistor transit frequency was measured to be about 7 GHz at $V_{CE} = 1$ V which corresponds to a 20 ps transit time. The chip power consumption is 220 mW. Fig. 2 shows the MUX mounted in a leadless chip carrier.

INJECTION LASER MODULATION

The current-switch version of the 4:1 MUX IC was then used for modulating a transverse junction stripe (TJS) laser at 2.24 Gbit/s (Mitsubishi ML-2205; .83 µm wavelength; approx. 17 mA threshold current; optical fiber pigtail). The value of 2.24 Gbit/s is expected to be the next higher stage in the planned European PCM hierarchy and is the intended bit rate for the trunk lines in the above-mentioned integrated services network (6). As indicated in Fig. 1, the laser diode is driven directly by the output buffer stage of the MUX IC; no external driver amplifier is required. As detector a high-speed silicon avalanche photodiode (BPW 28) was employed followed by a wideband amplifier (3 GHz). The signals are displayed on a sampling oscilloscope.

Typical examples of the monitored electrical MUX output and of the photodetector response at the experimental bit rate of 2.24 Gbit/s are shown in Fig. 3 for two static data input patterns. Fig. 3a

0149-645X/84/0000-0187 $01.00 © 1984 IEEE

refers to an NRZ 0111 bit pattern, whereas Fig. 3b shows the waveforms for a 1100 pattern. The modulation current swing amounted to 4 mA at a bias current of about 22 mA, leading to an optical output swing of about .32 mW. No appreciable ringing (relaxation oscillation of the laser diode) occured in the optical output at this bias value.

CONCLUSIONS

It was shown that direct laser-diode pulse-code modulation at 2.24 Gbit/s can be performed by a fast monolithic integrated bipolar circuit. The laser diode employed was a TJS laser with a threshold current of about 17 mA. The modulation current swing amounted to 4 mA.

A change to oxide-wall isolation, which is undertaken presently, should further increase the achievable bit rate of the MUX/laser driver IC. If, in addition, the structural dimensions of the IC are reduced in accordance to bipolar scaling rules (8), bit rates of silicon MUX's (and of comparable circuits) up to 4 Gbit/s do not seem out of reach.

In our Institute 4:1 MUX performance quite recently extended to 3 Gbit/s operation (2-stage structure) (9); no laser modulation experiment so far.

ACKNOWLEDGEMENTS

We would like to thank the Berlin Heinrich-Hertz-Institut for providing the injection laser. This work was funded in part by the German Ministry of Research and Technology.

REFERENCES

(1) B.G. Bosch, "Gigabit electronics - a review", Proc. IEEE, Vol. 67, pp. 340-379, 1979.
(2) U. Barabas, U. Langmann, and B.G. Bosch, "Diode multiplexer in the multi-Gbit/s range", Electron. Lett., Vol. 14, pp. 62-64, 1978.
(3) G.D. McCormack, A.G. Rode, and E.W. Strid, "A GaAs MSI 8-bit multiplexer and demultiplexer", Tech. Dig., 1982 GaAs IC Symp., pp. 25-28.
(4) J.K. Carney, M.J. Helix, and R.M. Kolbas, "Gigabit optoelectronic transmitters", Tech. Dig., 1983 GaAs IC Symp., pp. 48-51.
(5) A.D. Welbourn, G.L. Blan, and A.W. Livingstone, "A high speed GaAs 8-bit multiplexer using capacitor-coupled logic", IEEE J. Solid-St. Circ., Vol. SC-18, pp. 359-364, 1983.
(6) C. Baack, G. Elze, and G. Heydt, "A fiber-optic broadband integrated services network for the subscriber area", Proc. 1983 Europ. Conf. Optical Commun., pp. 339-342.
(7) H.-M. Rein, D. Daniel, R.H. Derksen, U. Langmann, B.G. Bosch, "A Time Division Multiplexer IC for Bit Rates up to about 2 Gbit/s", IEEE J. Solid-State Circuits, 1984, Vol. SC-19, No. 3.
(8) P.M. Solomon and D.D. Tang, "Bipolar circuit scaling", Dig. Tech. Papers, 1979 IEEE Intern. Solid-St. Circ. Conf., pp. 86-87.
(9) H.-M. Rein und R.H. Derksen, "An integrated time-division multiplexer for bit rates up to 3 Gbit/s", to be published.

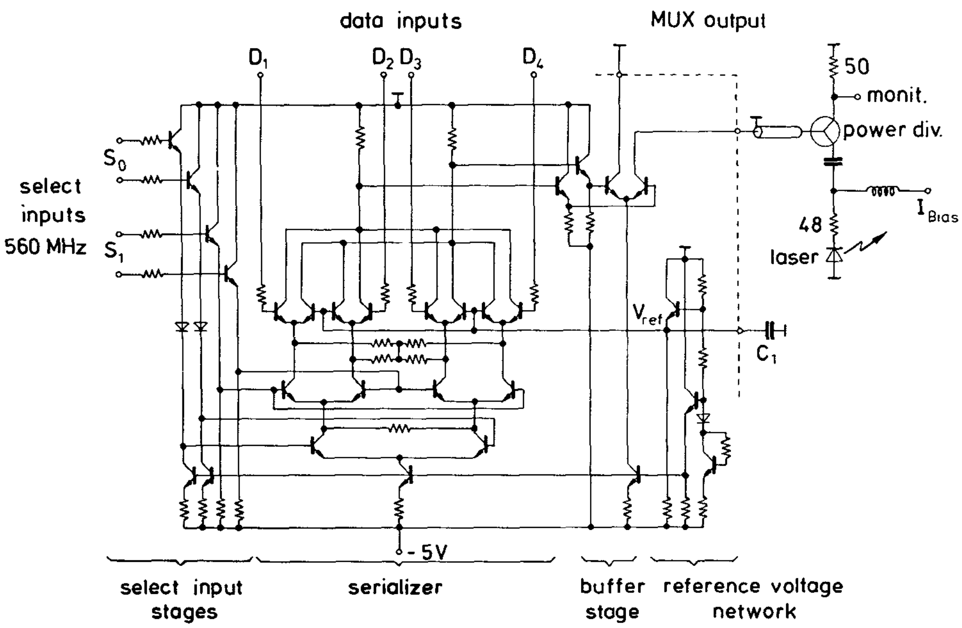


Fig. 1 Circuit diagram of multiplexer IC driving injection laser

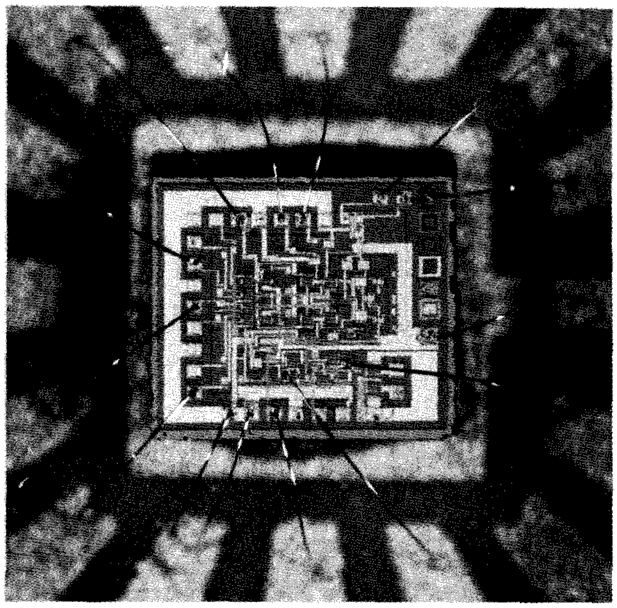
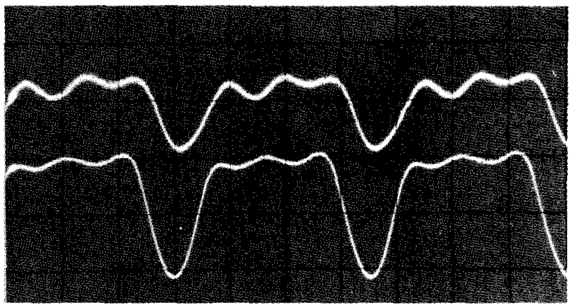
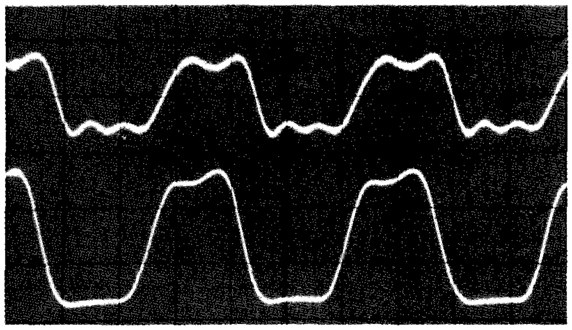


Fig. 2 MUX IC mounted in leadless chip carrier

a)



b)



vert.: 0.1 V/div.; horiz.: 0.5 ns/div.

Fig. 3 Different bit patterns at 2.24 Gbit/s
upper trace: detected laser response
lower trace: monitored MUX output
a) 0111 pattern;
b) 1100 pattern.