radiometer.[7] The result is shown in Fig. 3c. (Note that for $\lambda > 1{\cdot}5$ μm, the absorption depth[4] increases rapidly beyond the depletion-layer width, so that at high frequencies the quantum efficiency may be significantly lower than is indicated by this c.w. measurement.)

We may now analyse the leakage noise. The total leakage current is given by

$$I_{dtotal} = I_{ds} + M_d I_{dB} \tag{4}$$

where I_{ds} is surface leakage, I_{dB} is unity-gain bulk leakage and M_d is the mean multiplication appropriate to I_{dB}. The voltage dependence of the total leakage current was found to be described within 1% for $10 < M_d < 30$ with $I_{ds} = 3{\cdot}33$ μA, $I_{dB} = 173$ nA, and using for M_d the photocurrent multiplication values for $\lambda = 1{\cdot}7$ μm (to approximate to uniform generation of carriers throughout the device). By plotting $(\phi - 2)$ against $(M_d - 3/2)$ for $I_{in} = I_{dB} = 173$ nA, a value of k_w between 1·3 and 1·5 was found to be appropriate, in rough agreement with the result for 1·7 μm radiation. This demonstrates that leakage noise will dominate over signal noise at room temperature for power levels up to several hundred nanowatts.

Discussion: In designing a device specifically for optical communications at wavelengths beyond 1 μm, some improvement in k_w may be expected if a p^+-n structure is adopted, since the bulk of the unity-gain photocurrent will consist of holes, giving lower excess noise.

Such a device has recently been reported,[8] giving an excess noise factor F of 7 at $\lambda = 1{\cdot}4$ μm and $M = 10$, compared with $F = 11$ for a similar n^+-p device. Under the same conditions, the TIXL57 gave $F = 8$. However, leakage noise will still dominate if the unity-gain photocurrent is less than the unmultiplied bulk leakage current.

Conclusion: This letter has described the noise and responsivity of the Texas TIXL57 (formerly a commercial product) in terms of its potential for application to optical communications at wavelengths beyond 1 μm. In spite of mixed carrier injection, the variation of noise-current spectral density is well described by the theoretical expression for unilateral carrier injection, though further work is necessary to determine whether this method is applicable to Ge a.p.d.s in general. The dominant noise source (for incident power levels up to several hundred nanowatts) is the bulk leakage current, whose unmultiplied value is estimated to be ≈ 170 nA at 20°C.

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M.O.S. NEURAL PULSE MODULATOR

Indexing terms: Metal-insulator-semiconductor devices, Neural networks

Through control of the substrate-source voltage of the input transistor, output pulses can be controlled and modulated in an m.o.s. neural line.

Introduction: It is felt that a good deal of the information carried in biological neural systems is carried in the occurrence times and frequencies of action potentials for which several system and circuit models have been proposed.[1,2] Within the recent simple electronic realisations of neural lines, it has been shown that amplitude variation of an otherwise steady input can be used to obtain corresponding variations in output pulse repetition rates.[3,4] Here we show that additional or alternative control can result from a basic m.o.s.f.e.t. circuit[5] by modulation of the substrate-source voltage of the input transistor. This has the advantage of yielding another means of selectively cancelling output pulses[6] as well as giving a very controllable means of modulation, a property not at present available in bipolar realisations of the neural line.

Potential applications for the circuit have already been proposed,[2] and general uses of neural lines can be found in References 7 and 8 and include simulation of biological neural systems, communications systems and neuristor digital systems.

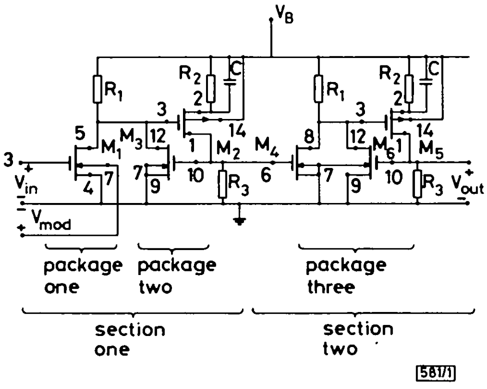

Fig. 1 *Two-section three-package neural line circuit*

Pin numbers for MC14007 package. $R_1 = R_2 = 5{\cdot}6$ kΩ, $R_3 = 2{\cdot}7$ kΩ, $C = 270$ pF, $V_B = 10$ V

Circuit and operation: Fig. 1 shows two sections of a unilateral positive-pulse neural line where, however, the input (n-channel) transistor M$_1$ has its substrate fed by a modulating voltage, $v_{mod} \leq 0$, rather than grounded. The operation of the unmodulated circuit is described in detail in Reference 5. Normally, when $v_{mod} = 0$ input voltage, $v_{in} \geq 0$, is above threshold, an action potential pulse occurs at the output, $v_{out} \geq 0$. If now $v_{mod} < 0$ is applied then a larger magnitude input voltage is needed to turn on the input transistor, this turn-on voltage being variable with v_{mod}.[9] Consequently, by making v_{mod} sufficiently negative, the input section can be selectively turned off. Experimentally the first section is found to turn off very rapidly through the use of v_{mod} and more interestingly when v_{mod} returns to ground potential an output pulse results when v_{in} remains above threshold.

Fig. 2 shows experimental verification of this phenomenon. For Fig. 2 a Tektronix FG502 function generator was used to generate a slow square-wave input v_{in}. The trigger output of the FG502 was then fed to the trig/gate input of a Tektronix PG508 pulse generator to gate on a negative-going paired pulse output which then served as v_{mod}. Here, as seen in Fig. 2a where $v_{mod} \equiv 0$, v_{in} was such that one output pulse resulted (at pin 1 of package 3), this occurring as v_{in} goes positive. In Fig. 2b the effect of a two-volt dual pulse v_{mod} is seen; the first output pulse is delayed until after the first v_{mod} pulse. Then, when the second v_{mod} pulse occurs at a time greater than the refractory period, a second output pulse occurs; this is for any v_{mod} pulse greater than about 1/4 V. Note that, as v_{mod} was gated on by v_{in}, two sets of dual v_{mod} pulses are seen, the PG508 repetition rate being set in the 50 kHz range and the FG502 at an 8 kHz rate.

Consequently the experiments show that, by pulsing v_{mod} at the same rate as v_{in} is pulsed, an output can be negated allowing pulse selection. If v_{in} is held above unmodulated threshold then a pulse in v_{mod} will trigger an output when it goes to zero, thus allowing modulation, and these phenomena occur over a large range of v_{mod}, including quite small magnitudes, thus allowing good control of the phenomena.

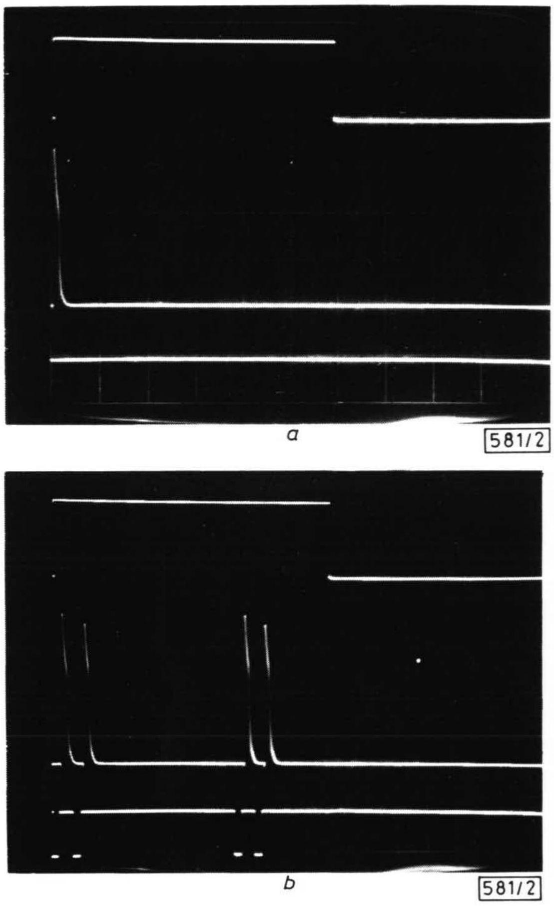

Fig. 2 *v_{in}, v_{out}, and v_{mod}*
(*a*) $v_{mod} \equiv 0$
(*b*) $v_{mod} \not\equiv 0$
Horizontal ≃ 10 μs/div; triggered by v_{in}
Verticals = 2 V/div
Zeros: v_{in} = 2nd graticule from top
v_{out} = 6th graticule from top
v_{mod} = 7th graticule from top

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CHANNELLED-SUBSTRATE NARROW-STRIPE GaAs/GaAlAs INJECTION LASERS WITH EXTREMELY LOW THRESHOLD CURRENTS

Indexing terms: Gallium arsenide, Semiconductor junction lasers

Channelled-substrate GaAs/GaAlAs injection lasers with very narrow current-confining stripe contacts are described. They have threshold currents less than half those previously reported for this type of device. The best devices had a room-temperature threshold current of only 12 mA pulsed and 14 mA c.w. The lasers also have very good high-temperature performance and c.w. operation has been obtained up to 160°C.

Introduction: Since the first reports on channelled-substrate lasers[1,2] many other workers have reported slightly modified and improved structures.[3–6] The main advantage of the channelled-substrate structure when compared to other advanced laser structures with built in optical waveguides is the simplicity of the manufacturing process. The optical waveguide in the plane of the *p-n* junction is formed automatically during the liquid-phase epitaxy (l.p.e.) process normally used for the growth of the heterostructure layers.

There are two different types of optical waveguide. In one type, the active-layer thickness varies across the waveguide to form a crescent shape which results in a higher effective refractive index beneath the axis of the stripe than at the edges.[2] There are others, such as the well known channelled-substrate planar (c.s.p.) laser,[3,4] in which the active layer is of uniform thickness with the waveguide being formed by the loading effect of the substrate which comes very close to the active layer (within 0·4 μm) on either side of the channel. This c.s.p. structure is unsuitable for obtaining the very lowest threshold currents because fairly high optical losses are an inevitable penalty of this type of optical waveguide.[4] To obtain very low threshold currents we have therefore chosen to combine a channelled substrate with a crescent-shaped optical waveguide

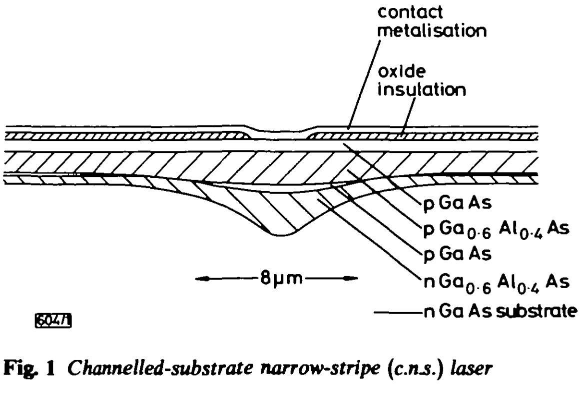

Fig. 1 *Channelled-substrate narrow-stripe (c.n.s.) laser*