A short time after every switching performed by the switch array S_i the output signal of the comparator is inhibited. This is so that the system can react on the switching before a new decision switching will come. This means that if the input SOP is fixed, δ_x and δ_y will both exhibit a sort of triangular-wave shape. If the input SOP is varying slowly, a slowly varying component will be added to this 'triangular wave'.

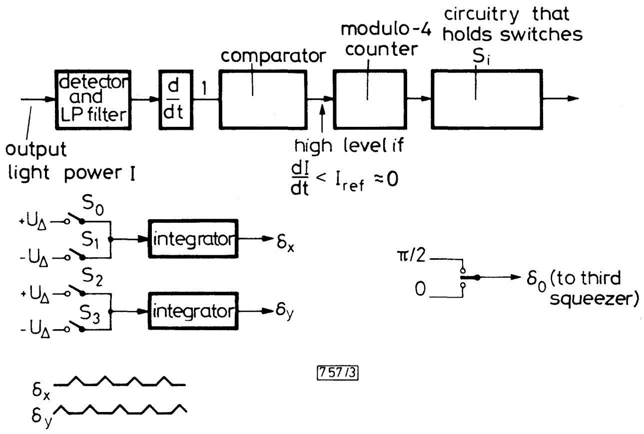

Fig. 3 *Implementation of electronic system for deriving the control signals δ_x, δ_y and δ_0 from the polarised output light power $\pm U_\Delta$ are direct voltages*

The signal δ_0 controls the above-mentioned third squeezer in front of A; B and is switched from 0 to $\pi/2$ rad or vice versa if $\delta_y \neq n\pi$ (this is determined by comparators on the signal δ_y).

The assumption for proper function is of course that the effect of the input SOP on dI/dt is small compared to the effect caused by $d\delta_x/dt$ and $d\delta_y/dt$. This slew-rate condition is what limits the speed of the system (the values of $d\delta_x/dt$ and $d\delta_y/dt$ are, of course, limited by the speed of the squeezers).

Experimental results: The system described above was used with a 1·3 μm laser diode (Hitachi HLP 5400) and a conventional single-mode fibre (Sumitomo ES-1) to demonstrate polarisation-stabilised operation.

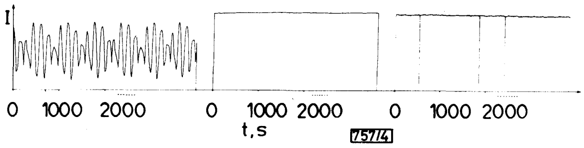

Fig. 4 *Linearly polarised light output power in three cases*

Input polarisation disturbance switched on and polarisation stabilisation off (left), input polarisation disturbance off and stabilisation on (middle) and both disturbance and stabilisation on (right). Note reset glitches in the right curve, and the highly stable output with stabilisation on. Also note time scale

Owing to the practical difficulties in testing the system in a realistic way with a narrowband spectrum laser and a long (several kilometre) fibre, a short fibre was used and the fluctuations of the input SOP were generated artificially by two additional squeezers driven by two incoherent triangle wave generators so the input SOP was fluctuating within a great range. Fig. 4 shows typical results for the output intensity I of the system described above, in three cases:

(i) with SOP disturbance switched on and stabilisation switched off

(ii) with a steady-state input SOP (only the 'natural' disturbances) and stabilisation on

(iii) with SOP disturbance switched on and stabilisation switched on. Note the three 'resets' caused by δ_x or δ_y reaching forbidden areas.

The stability was better than 0·1–0·2 dB. The resets, of course, caused larger deviations. In order to find out whether the squeezing caused significant power loss a measurement (with mode stripping of the fibre) was carried out. Three squeezers, each giving a retardation of 4π rad with a length to the fibre of 15 mm each were used. The loss was then measured to be less than 0·1 dB.

Conclusions: An active polarisation stabilisation scheme for single-mode fibres has been described. The system employs two or three fibre squeezers to induce linear birefringence and a linear polariser. This scheme implements the polarisation stabilisation feedback in a digital electronic system instead of, as previously, in a complex optical system.

The present implementation can compensate drift rates of up to ~0·3 rad/s, higher rates are achievable by using faster squeezers, since this scheme relies on the polarisation fluctuations being slower than the changes induced by the probe signals of Fig. 3.

The operating characteristics were discussed and active polarisation stabilisation in a 1·3 μm single-mode fibre optic link was demonstrated.

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NOVEL ACTIVE COMPENSATED WEIGHTED SUMMER

Indexing term: Circuit theory and design

A new active compensated generalised weighted summer is given. The compensation is achieved by using two extra operational amplifiers and six resistors. The proposed summer has negligible phase and magnitude errors over an extended frequency range. The design equations are given and the tuning procedure is discussed.

Introduction: It is well known that the single operational amplifier (op-amp) weighted summer is suitable only for applications at low frequency due to the finite gain bandwidth of the op-amp. Recently several active phase compensated weighted summers using two op-amps have been introduced in the literature.[1–4] It has been shown that for low frequencies the two op-amps compensated summer has phase and magnitude errors proportional to $(\omega/\omega_t)^3$ and $(\omega/\omega_t)^2$, where ω_t is the unity gain bandwidth of the op-amp; that is, the phase error of the two op-amps summer is reduced to a negligible level, whereas the magnitude error remains a second-order term as that of the uncompensated summer.

Most recently active compensated amplifiers using three op-amps have been considered.[5,6] The circuits reported in References 5 and 6 are not suitable by their nature for realising a generalised weighted summer for both positive and negative gains.

The purpose of this letter is to introduce a novel active compensated generalised weighted summer. The new summer circuit employs three op-amps and resistors.

Proposed compensated summer: The new active compensated generalised weighted summer is shown in Fig. 1. The voltages $V_{11}, V_{12}, \ldots, V_{1m}$ represent the m inverting inputs, and the voltages $V_{21}, V_{22}, \ldots, V_{2n}$ are the n noninverting inputs.

Let the open-loop gain of each of the three op-amps be represented by the single-pole model

$$A_i(s) \simeq \omega_{ti}/s \qquad i = 1, 2, 3 \quad (1)$$

where ω_t is the unity gain bandwidth of the op-amp. By direct circuit analysis, the generalised expression of the output voltage V_0 is given by

$$V_0 = \left[\frac{K}{G}\sum_{i=1}^{n}(V_{2i}G_{2i}) - \frac{(K+1)}{G^-}\sum_{i=1}^{m}(V_{1i}G_{1i})\right] \times \left[\frac{K_1(K_3+1)}{(K_2+1)}\right]\varepsilon(s) \qquad (2)$$

where

$$G = \frac{1}{R} = \sum_{i=1}^{n} G_{2i}$$

$$G_{2i} = \frac{1}{R_{2i}} \qquad i = 1, 2, \ldots, n \quad (3)$$

$$G^- = \sum_{i=1}^{m} G_{1i}$$

$$G_{1i} = \frac{1}{R_{1i}} \qquad i = 1, 2, \ldots, m \quad (4)$$

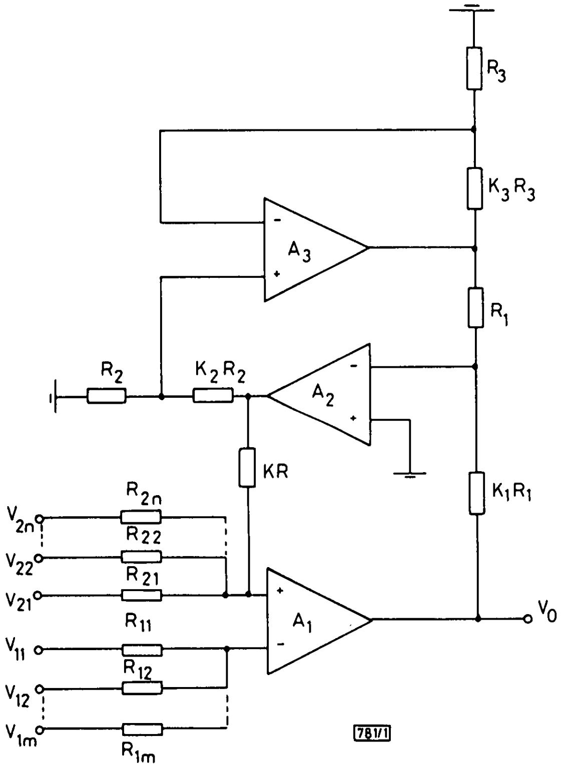

Fig. 1 *Novel active compensated weighted summer*

$\varepsilon(s)$ is the error function of the compensated circuit and is given by

$$\varepsilon(s) = 1 + s\tau_2\left[\frac{(K_1+1)}{K_1(K_3+1)}\right] + s^2\tau_2\tau_3\left[\frac{(K_1+1)}{K_1(K_3+1)}\right] \Big/ \left\{1 + s\tau_3 + \left(\frac{K+1}{K_2+1}\right)\left[s\tau_1\frac{K_1(K_3+1)}{(K_1+1)} + s^2\tau_1\tau_2 + s^3\tau_1\tau_2\tau_3\right]\right\} \qquad (5)$$

where

$$\tau_i = \frac{K_i + 1}{\omega_{ti}} \qquad i = 1, 2, 3 \quad (6)$$

Examining eqn. 5 for the remaining phase and magnitude errors, it is seen that taking

$$\tau_3 = \tau_2\left[\frac{(K_1+1)}{2K_1(K_3+1)}\right] = \tau_1\left[\frac{K_1(K+1)(K_3+1)}{(K_1+1)(K_2+1)}\right] \qquad (7)$$

will yield relatively negligible phase and magnitude errors over a prescribed frequency range. The compensated error function simplifies to

$$\varepsilon_c(s) = \frac{1 + 2\tau_3 s + 2\tau_3^2 s^2}{1 + 2\tau_3 s + 2\tau_3^2 s^2 + 2\tau_3^3 s^3} \qquad (8)$$

From the above equation, it is seen that the phase and the magnitude errors of the compensated summer circuit are given, respectively, by:

$$\phi_c \equiv \arg[\varepsilon_c(j\omega)] \simeq 2(\omega\tau_3)^3$$
$$\gamma_c \equiv |\varepsilon_c(j\omega)| - 1 \simeq 4(\omega\tau_3)^4 \qquad \omega\tau_3 \ll 1 \quad (9)$$

Thus if the compensation conditions given by eqn. 7 are satisfied and at frequencies such that $\omega \ll \omega_{t3}/(K_3+1)$, the phase error is reduced to a third-order term and the magnitude error is reduced to a fourth-order term.

Tuning of summer circuit: The DC gain requirement can be adjusted by tuning the resistor K_3R_3. The compensation conditions can be satisfied by tuning the resistors KR, K_1R_1 and K_2R_2. Choosing $K = K_2$, the design equations for K and K_1 are obtained from eqn. 7 and are given by:

$$K_1 = \omega_{t1}/\omega_{t3} \qquad (10)$$

$$K = K_2 = \left(\frac{2K_1}{K_1+1}\right)(K_3+1)^2(\omega_{t2}/\omega_{t3}) - 1 \qquad (11)$$

Thus it is seen that it is not necessary to use matched op-amps with this generalised summer. If matched op-amps are used, however, the design equations simplify to:

$$K_1 = 1 \qquad (12)$$

$$K = K_2 = K_3(K_3+2) \qquad (13)$$

Conclusions: A novel active compensated generalised weighted summer is given. The proposed summer employs two extra op-amps and six resistors more than the conventional single op-amp summer. The compensated summer has negligible phase and magnitude errors over a prescribed frequency band.

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COMMENT

EXTENDED CALIBRATION AID FOR SIX-PORT NETWORK ANALYSERS

In Reference A Potter and Snowden propose an improved iteration convergence criteria for use with the six-port calibration procedure which we developed.[B] This procedure uses