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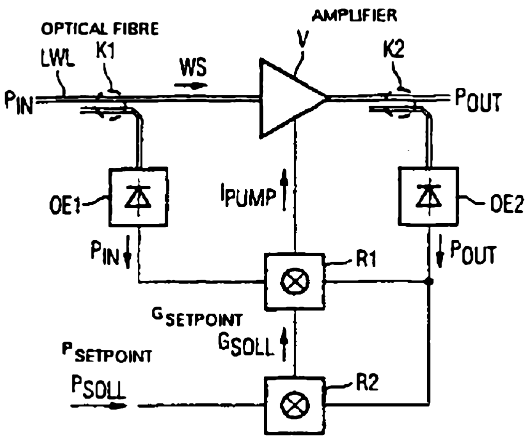


(57) Abstract

The invention relates to regulated optical amplifiers (V) for wavelength multiplex signal transmission, which each comprise a first regulator (OE1, OE2, R1) for regulating transmission gain and a second dominant regulator (OE2, R2, R1) whose regulation behaviour is considerably slower and permits regulation of the output level (P_{OUT}) in accordance with a setpoint (P_{OUT}) being applied. In a transmission line fitted with such amplifiers both rapid changes in level and slow changes in damping in said transmission line can be corrected.

Description

Optical amplifiers and optical transmission path

The invention relates to controlled optical amplifiers and optical transmission paths in which these amplifiers are used.

Optical amplifiers are used in optical transmission networks to compensate for fiber attenuation. However, stable operation over additional transmission paths is possible only if changes to system parameters are compensated with the aid of controllers. In previously used wavelength division multiplex transmission systems, the sum output powers of the amplifiers are controlled. In single-channel systems or paths with a constant number of channels, slow changes to system parameters - for example due to temperature fluctuation or aging - are effectively compensated by this control concept.

However, if the number of channels changes during operation, a sum output power control of this type modifies the levels of the individual WDM transmission channels. A level change of this type can essentially be avoided by determining the number of active channels and informing the control devices of the individual optical amplifiers. These accordingly adapt the required value for the output level of the amplifier. However, due to the different time constants, this level adaptation does not normally succeed without transient fluctuations, which are associated with substantial transmission quality losses.

A different possible solution comprises the control of the individual amplifiers for constant gain (amplification). Amplifiers of this type are described in "Electronic Letters", 26th March, 1991, Vol. 27, no. 7, p

560 - 561 and "Electronic Letters", 9th June, 1994, Vol. 30, no. 12, p 962 - 964. In these circuits, if the number of active channels changes, the level fluctuations of the remaining channels are suppressed by holding the gain constant. However, this control principle is also unsuitable as a control concept for a transmission path with a plurality of amplifiers, since slow changes in the path parameters are added together, resulting in a deterioration in transmission quality.

The object of the invention is therefore to indicate suitable amplifiers for optical transmission networks. Furthermore, the transmission paths are to be designed in such a way that, even if the number of channels changes, the reception levels of the individual WDM channels remain constant.

The object is achieved by means of a controlled optical amplifier according to claim 1. A variant of the amplifier is indicated in an independent claim 3.

The transmission paths equipped with these amplifiers are described in claims 6 and 7.

Advantageous further developments are described in each case in dependent claims.

The advantage of the optical amplifier according to the invention lies in that the gain control operates in the first control circuit with a short time constant. Changes in the number of active WDM channels therefore have only a minimal effect on the output levels. The second control circuit ensures that slow changes are compensated. If the number of active channels changes, a corresponding change in the required value of the second control circuit is carried out by means of a terminal (network node), either at the transmitting end, inserted locally in the transmission path or at the receiving end, so that the output level control - if provided - is perceptible for only a short time and to only a minimal extent.

If a memory unit is provided in the second control circuit, it is thus possible to allow this control circuit to be active only at specific times in order to modify the reception level or de-activate it during a change in the number of channels.

In the alternative solution, the output power is controlled either jointly for all amplifiers of one transmission path from the reception terminal or, with corresponding, individual monitoring of the output levels, also separately via a correspondingly designed monitoring channel.

Through the use of an output level control, the amplifiers only require information on the number of WDM channels, or receive a corresponding required value.

The transmission paths equipped with these amplifiers can also compensate for slow amplification changes caused by aging processes.

The invention is described in more detail with reference to two embodiments, wherein:

Figure 1 shows a basic circuit diagram of the amplifier according to the invention with output power control,

Figure 2 shows a basic circuit diagram with an optical fiber amplifier,

Figure 3 shows a transmission path with a plurality of amplifiers,

Figure 4 shows a variant of the amplifier according to the invention, and

Figure 5 shows the use of this amplifier on a transmission path.

An embodiment of the invention is shown as a basic circuit diagram in **Figure 1**. An optical amplifier V serves to amplify a wavelength division multiplex signal

MS which is transmitted via an optical waveguide LWL. At the input side, a first measurement coupler K1 is provided, which taps part of the signal. This part is converted by a first opto-electronic transducer OE1 into an electrical measurement signal P_{IN} corresponding to the input level (input sum power) P_{IN}, which is fed to a first controller R1. Similarly, a measurement signal P_{OUT}, which corresponds to the output power P_{OUT} and which is likewise fed to the first controller, is obtained via a second measurement coupler K2 and a second opto-electronic transducer OE2. Depending on the (adjustable ratio) P_{OUT} to P_{IN}, for example, the pump current I_{PUMP} in an optical-fiber amplifier or the control current in a semiconductor amplifier is controlled. Other gain control principles can equally be applied, which, for example, are described in the cited literature.

Apart from a first control device (control circuit, shown in simplified form) (K1, OE1, K2, OE2, R1, V) which is used for fast gain control, a second dominant control device (control circuit K2, OE2, R2, R1, V) is provided, which controls the output power (output level) P_{OUT} through comparison of the corresponding measurement value p_{OUT} with a feed parameter, the required value p_{SOLL}. Slow changes in transmission loss, caused, for example, by a change in temperature or aging, are compensated by this second control circuit. By acting on the first control circuit, the setting parameter G_{SOLL} output by the second controller R2 determines the pump current and therefore the gain of the optical amplifier. If the number of transmission channels changes, the gain should not change. The level control must not therefore become immediately active, which can be achieved by means of a time constant of the second control circuit which is normally very much greater than the time constant of the first control circuit.

Figure 2 shows details of the amplifier circuit with an optical fiber amplifier VFA, whose gain is determined by the pump current I_{PUMP} generated by a controlled pump laser PL, said current being injected via a pump coupler PK. The first controller R1 may contain an attenuator DG, which is connected to the second opto-electrical transducer OE2 and a first comparator COM1. If the second control circuit is left out, the gain can be adjusted with the attenuator. One possibility for "output level control through gain modification" would involve direct modification of the attenuator DG by means of the feed parameter p_{SOLL}.

In the embodiment, the comparison between the output power and the feed parameter P_{SOLL} takes place in the second control device (in the second control circuit) K2, OE2, COM2, MU, IN, COM1, PL, PK, VFA - as already described in principle - in a second comparator COM2. Via the multiplier MU, the result of this comparison modifies the input signal of the first comparator COM1 and in this way controls the pump current and therefore the gain of the optical fiber amplifier VFA. The attenuator can be dispensed with, since the second control circuit determines the gain via the multiplier.

As already mentioned, the time constant in the second control circuit should be adequately large so that, in the event of the change in the number of channels, it can neutralize the effect thereof by means of a corresponding externally performed modification of the feed parameter. A memory unit SH may also be helpful for this purpose. This can also be inserted between the integrator and the multiplier. A range of around 1 microsecond to one millisecond is adequate as a time constant for the first control circuit at high data rates in the megabit/second range, whereas a range of around 0.1 second to several seconds, minutes and hours is appropriate for the second control circuit. The time constant can also be switched over for different operating conditions.

A small time constant of, for example, 100 microseconds can therefore be selected for commissioning, whereas, in the event of a change in the number of channels, a time constant of 1 sec and, if a required level modification is carried out, a time constant of several minutes may be appropriate.

An integral action or at least an integral component, which can also be supplemented by a dead time, is suitable for the second controller. The second comparator and the integrator can be combined in a circuit design.

The amplifier circuits with the associated control circuits may of course be designed in any required manner.

Figure 3 shows a transmission path with a plurality of optical amplifiers VT, V1 to Vn. In a transmission terminal T1, a wavelength division multiplex signal MS is generated in a transmission device TR with a downstream wavelength division multiplexer WDM, is amplified in an optical amplifier VT and inserted into the path. The amplifiers are set in such a way that they deliver output levels which correspond to the conditions of the relevant path section and which are maintained by the second control circuit even in the event of slowly changing transmission characteristics.

If the number of WDM channels changes, the output level initially continues to be held constant in each channel by means of the first control circuit. Due to the slow time constant/dead time, the output level controller does not initially act on the control process. Since the change in the feed parameter which serves to set the new output level is simultaneously signaled via a monitoring channel OCH from the terminal to the amplifiers, the second control circuit has virtually no effect. Separate channel number monitoring, which is allocated to each amplifier is, on the other hand, still too expensive.

It must also be noted that the output powers may also be individually adjustable via the monitoring channel.

Figure 4 shows a variant VV of the amplifier according to the invention. The second control device for direct control of the output level is missing. The gain can be set only via the monitoring channel OCH in order to be then held constant by the first control circuit. Thus, an external modification of the output level is in turn also possible. In this example the setting is determined via a digital/analog converter DAW, whose output signal as a control signal G_{SOLL} determines the gain.

Figure 5 shows a further transmission path with optical amplifiers VV1 to VVn, in which this amplifier type can be advantageously used. A terminal T2 at the receiving end contains not only an amplifier VVn and a wavelength demultiplexer WDD, but also a receiving device RE, which determines the sum level and the number of active WDM channels. From the second terminal, the numbers of channels or corresponding required values are indicated via the transmission channel OCH to the amplifiers and, in the event of system-related slow changes in the reception level, the extent to which the gain of the individual amplifiers is modified is also established. The second "control circuit" is thus always formed via the reception terminal. In simple embodiments of the setting device and amplifiers, the same gain modifications can be made for all amplifiers and, in more expensive designs, individual modifications can be made to individual amplifiers according to the path parameters or according to monitoring devices. By means of correspondingly designed controllers, the output levels can also be defined directly or modified in relation to predefined levels.

Claims

1. Controlled optical amplifier (V, V1, ...), in particular for wavelength division multiplex signal transmission, with a first control device (V, OE1, OE2, R1) for gain control,
characterized in that
a second dominant control device (V, OE, R2, R1) with a substantially slower control response is provided to control the output level (P_{OUT}) according to a supplied feed parameter (p_{SOLL}).

2. Controlled optical amplifier (V, V1, ...), according to claim 1,
characterized in that
the first control device is formed from an optical amplifier (PL, PK, VFA), a second opto-electrical transducer (OE2) connected to the output of the latter and a first comparator (COM1), to which a measurement signal (P_{IN}) corresponding to the input signal (p_{IN}) is fed via a first opto-electrical transducer (OE1), and
that the second control device is essentially formed from the optical amplifier (PL, PK, VFA), the opto-electrical transducer (OE2) connected to the output of the latter, a second comparator (COM2), to the second output of which a required value (P_{SOLL}) is fed, a multiplier (MU) inserted between the first opto-electrical transducer (OE1) and the first comparator (COM1), to which the output signal of the second comparator is fed, and the first comparator (COM1).

3. Controlled optical amplifier (VV, VV1, ...), in particular for wavelength division multiplex signal transmission, with a first control device (OE1, OE2, R1) for gain control,
characterized in that
a control device (DAW, IN, MU) is provided, with which

the output power (P_{OUT}) can be adjusted by setting the gain according to a required value (P_{SOLL}/G_{SOLL}) supplied as a feed parameter.

4. Controlled optical amplifier (VV, VV1, …) according to claim 3,
characterized in that
the first control device is essentially formed from an optical amplifier (PL, PK, VFA), a second opto-electrical transducer (OE2) connected to the output of the latter and a first comparator (COM1), to which a measurement signal (p_{IN}) corresponding to the input signal is fed via a first opto-electrical transducer (OE1), and
that the control device (DAW, IN, MU) contains a multiplier (MU), to which a control signal (G_{SOLL}) corresponding to the externally fed required value (p_{SOLL}) is fed.

5. Controlled optical amplifier (VV, VV) according to one of the previous claims,
characterized in that
it is designed as an optical fiber amplifier (PL, PK, VFA) and the pump current (I_{PUMP}) is controlled by the control devices.

6. Transmission path with a plurality of amplifiers (V, VV1, …) connected in series,
characterized in that
a required value (P_{SOLL}) which determines the relevant required output level (P_{OUT}) is supplied as a feed parameter to the amplifiers (V, VV1, …).

7. Transmission path with a plurality of optical amplifiers (VV) connected in series according to claim 3, 4 or 4 and 5,
characterized in that
a reception terminal (T2) is provided which monitors both the receiving-end sum level and the number of active WDM channels and, in the event of a change in the sum level

with a constant number of WDM channels, re-adjusts the gain of the optical amplifiers (VV1, ..., VVn) as part of the second control facility.

8. Transmission path according to claim 6 or 7, characterized in that a digital required value (P_{SOLL}) containing the number of active WDM signals is transmitted as the feed parameter.

9. Controlled optical amplifier (V, VV) according to claim 1, 2, 3 or 4, characterized in that the second control device (OE2, R2, R1; RE, DAW, MU, COM1, PL, VFA) has an integral-action component or is designed as an integral-action controller.

10. Controlled optical amplifier (V, V1, ...) according to claim 1, 2, 3 or 4, characterized in that the second control device has a dead-time component.

11. Controlled optical amplifier (V, V1, ...) according to claim 1, 2, 3 or 4, characterized in that the time constant of the second control device (OE2, R2, R1; RE, DAW, IN, MU, COM1, PL, VFA) can be switched over.

Abstract

Optical amplifiers and optical transmission path

The controlled optical amplifiers (V) for wavelength division multiplex signal transmission in each case have a first control device (OE1, OE2, R1) for gain control and a second dominant control device (OE2, R2, R1) with a substantially slower control response for controlling the output level (P_{OUT}) according to a supplied required value (p_{SOLL}). In the case of a transmission path equipped with these amplifiers, both fast level changes and slow loss changes in the transmission path can be compensated.

Figure 1

FIG 1

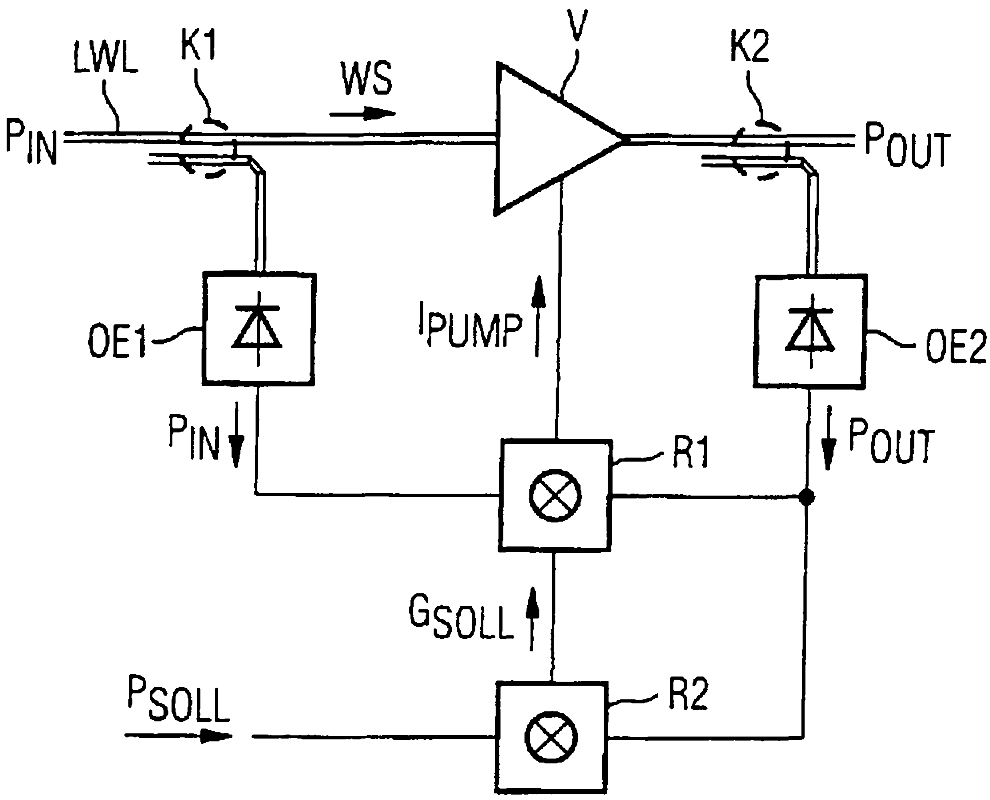


FIG 2

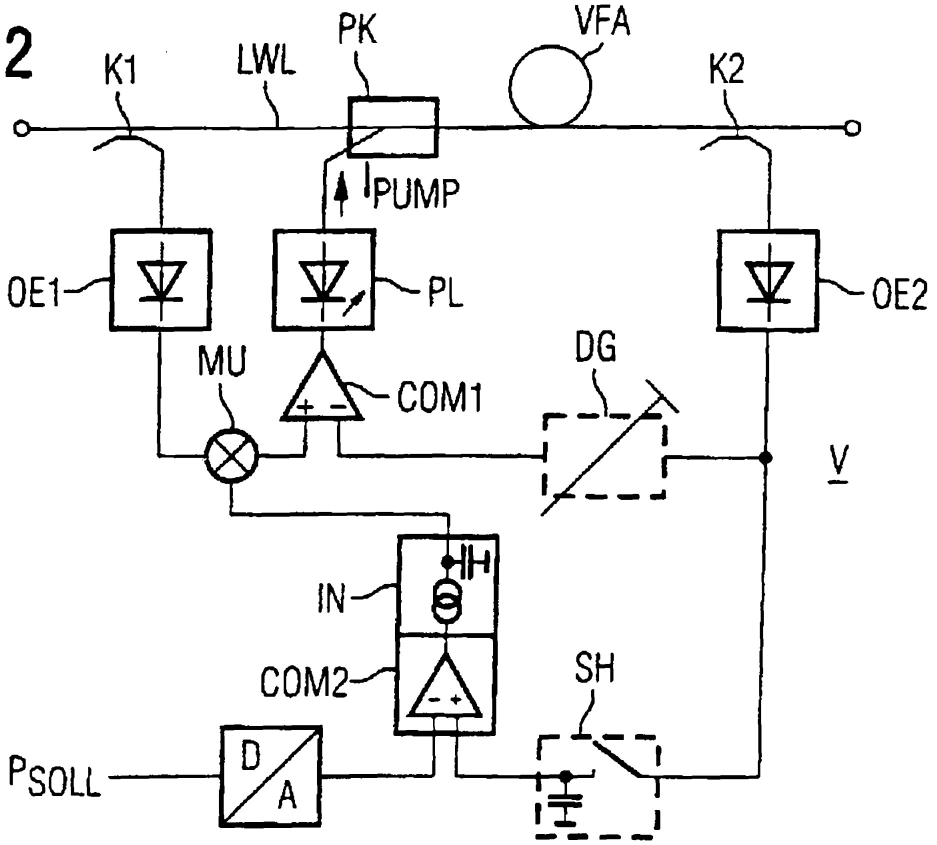
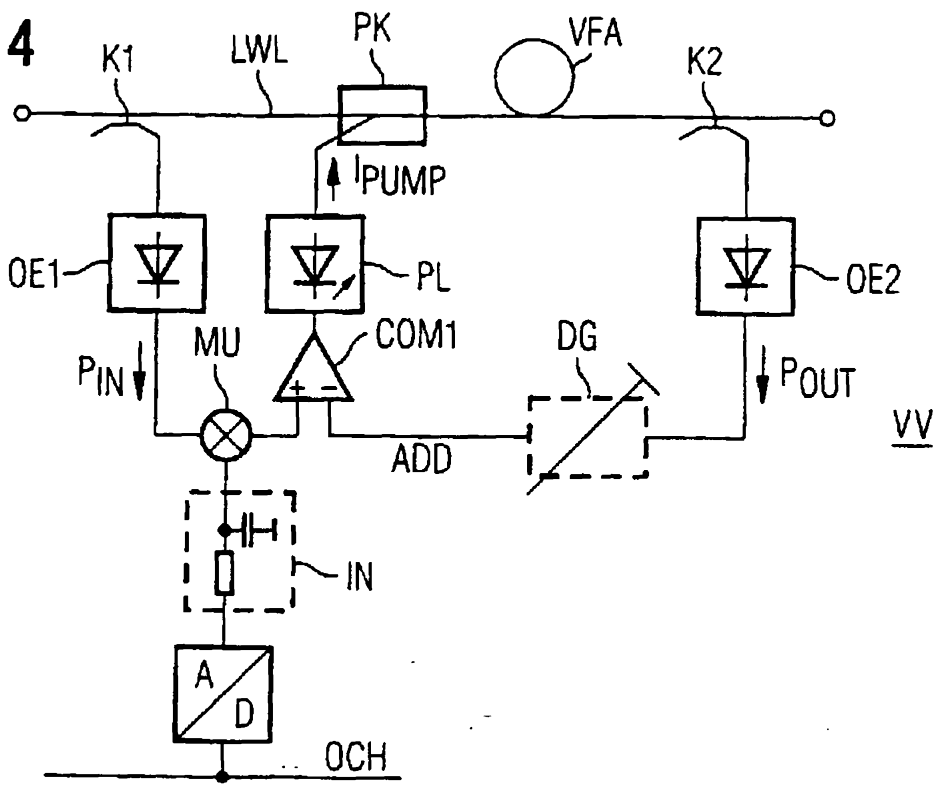

K1
LWL
PK
VFA
K2
I_{PUMP}
OE1
PL
OE2
MU
COM1
DG
V
IN
COM2
SH
P_{SOLL}
D
A

FIG 4


K1
LWL
PK
VFA
K2
I_{PUMP}
OE1
PL
OE2
MU
COM1
DG
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P_{OUT}
VV
ADD
IN
A
D
OCH

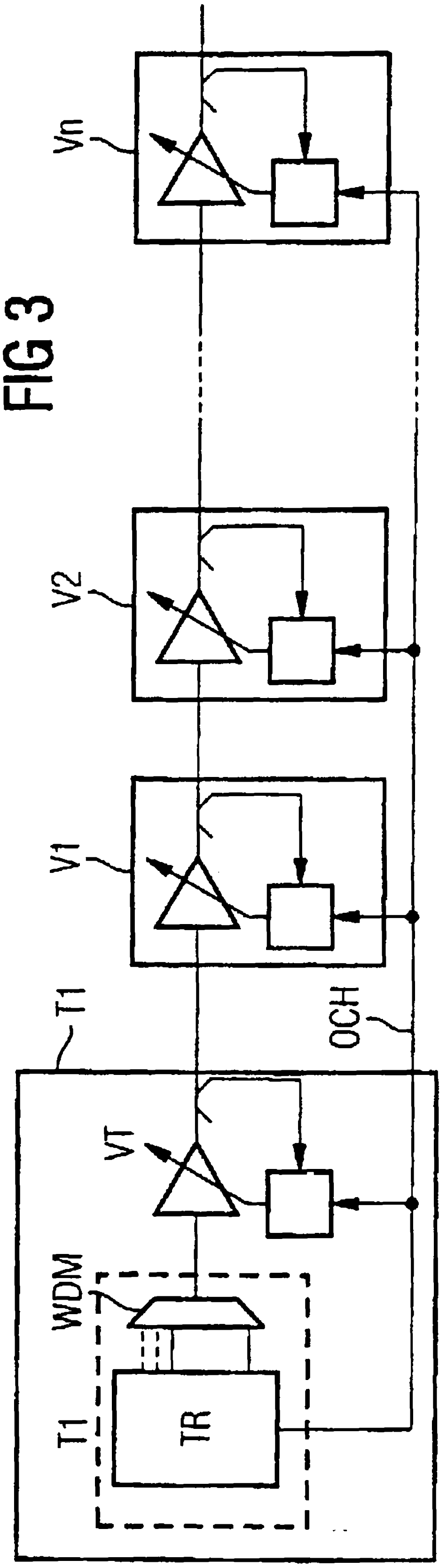

FIG 3

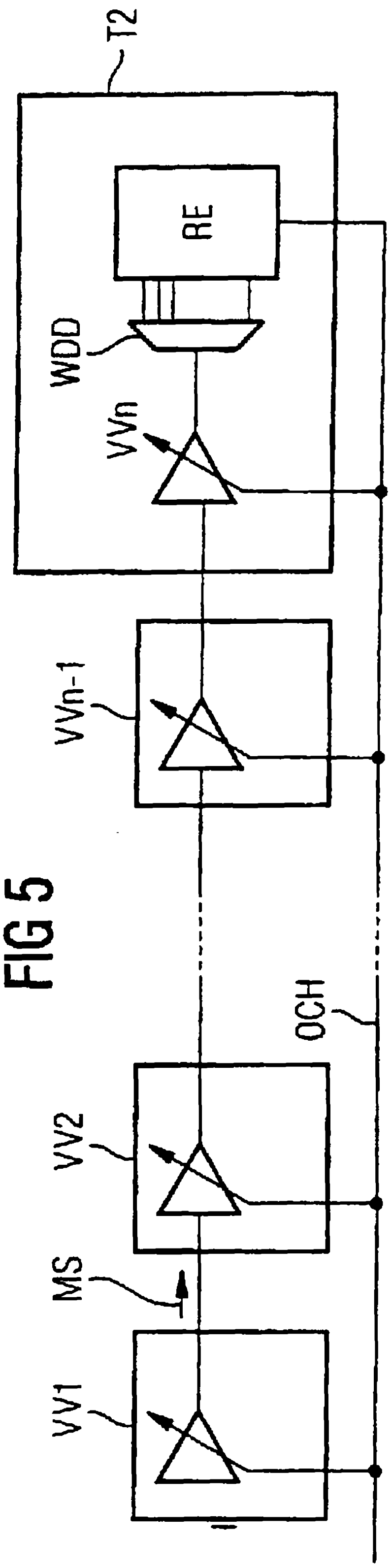

FIG 5