SIEMENS

Circuits for Laser Power Control

Description of Laser Behaviour

The laser diodes used in Siemens transmitters and BIDI™ are Fabry Perot GaInAsP lasers designed in MCRW (Metal Clad Ridge Waveguide) and SL MQW (Strained Layer Multi Quantum Well) structure. With a sufficiently high operating point, the maximum modulation frequency is determined more by the case feed than by the chip characteristics and lies roughly between 500 MHz and 1 GHz.

If the transmitters have to work in a wide temperature range (–20 °C up to 85 °C) without temperature stabilisation the temperature response of the laser must be considered in detail and power regulation circuits have to be used for stabilising the optical output signal.

Temperature response

The fundamental laws for changing the threshold current Ith and the power slope S are described in the application note: Enhanced thermal model of laserdiodes.

For designing the driver circuit the absolute limits over temperature range and life time (until end of life: EOL) are important. According to the data sheets the following values have to be used:

Variation of the laser parameters according to the data sheets					
	Temperature range –40 to 85 °C				
			Minimum	Maximum (EOL)	
		Ith	2	60	mA
			Minimum (EOL)	Maximum	
Slope low power			4	80	mW/A
Needed current for 0,4 mW peak			100	5	mA
Slope medium power			15	150	mW/A
Needed current for 1 mW peak			66,6	6,66	mA
Slope high power			25	250	mW/A
Needed current for 2 mW peak			80	8	mA

Regulation of the output power

Since the light-current characteristic of a laser diode is a function of temperature as shown above, the optical power and modulation depth have to be regulated via one or two control circuits.

Figure 1 shows the functional circuit diagram of the optical transmitter comprising the laser with monitor photodiode, the drive circuit for the bias current and the circuit for slow control of the average optical power. Only the average output power has be controlled. The modulation depth of the light power depends on the amplitude attached at the modulation input.

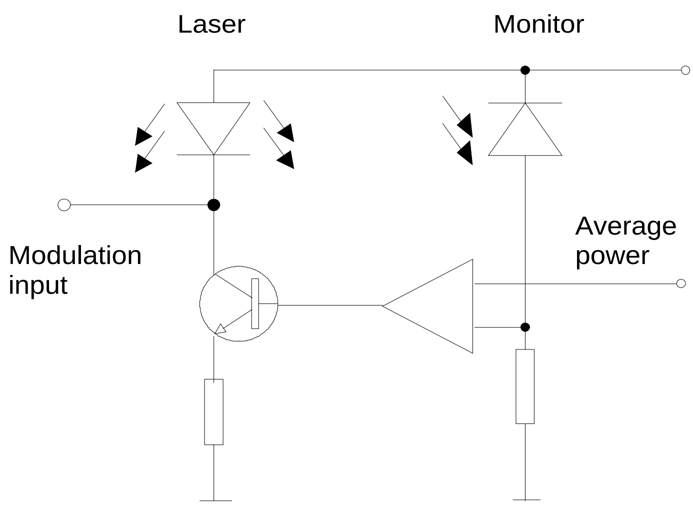

Figure 1
Basic power regulation circuit

In binary transmission the extinction ratio (power in low state divided by power in high state) is an important system term.

If it is not possible to modulate below the threshold and a precise extinction ratio is needed the optical power and modulation depth have be regulated via two control loops. One control loop causes the bias current Io to track the mean optical power. Laser slope variations are compensated by suitably controlling the modulation current Imod to ensure that the optimum operating point is maintained below the lasing threshold.

A circuitry which enables to realise two control loops is shown in **Figure 2**.

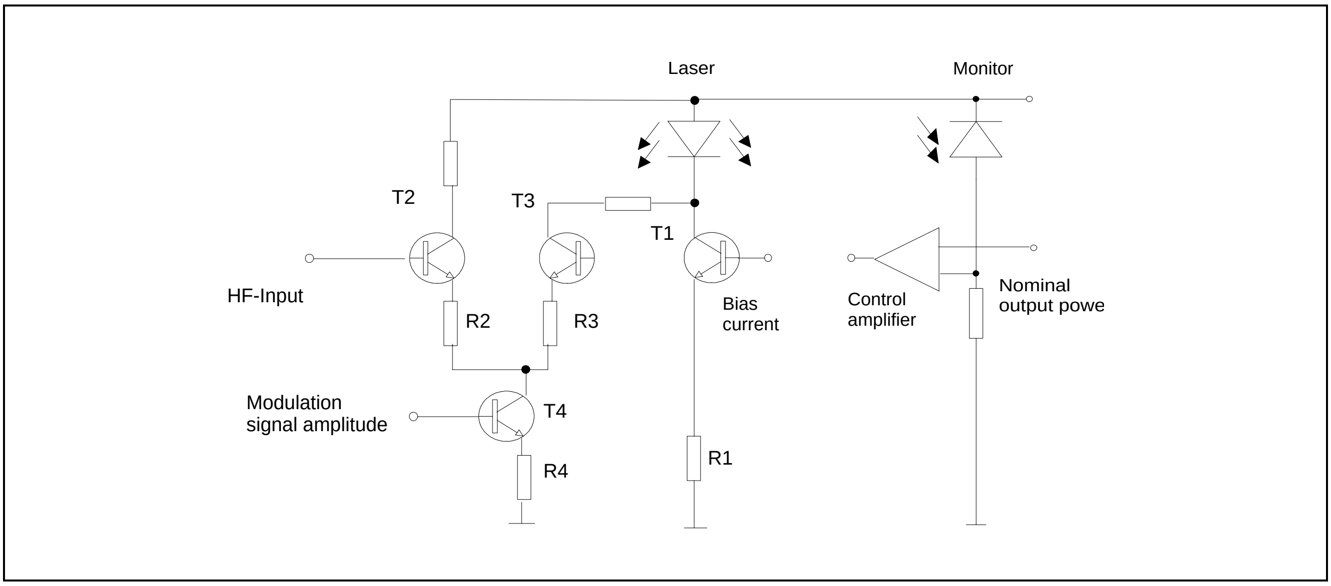

Figure 2
Basic power regulation circuit for two control loops

The control loops shown in **Figure 2** can work in different ways: controlled by the signal from the monitor photodiode or by the temperature of the laser. The function of these loops can be combined in different kinds:

	Bias current	Modulation current
A	Closed loop control with monitor	Fixed
B	Fixed	Closed loop control with monitor
C	Closed loop control with temperature	Closed loop control with monitor
D	Closed loop control with monitor	Closed loop control with temperature
E	Closed loop control with monitor	Closed loop control with monitor (via fast signal detection or pilot control)
F	Closed loop control with monitor	Coupled with the bias control loop
G	Coupled with the modulation current control loop	Closed loop control with monitor

A is often used due the easy design and adjusting. The disadvantage of fixed modulation current is the decreasing of modulated light with increasing temperature and ageing. At low temperature modulation below the threshold may occur and therefore this method is only usable at low datarates.

B may be used also only used at low data rates in the following way:

The laser should work with the lowest expected threshold current (minimum temperature) as bias current ("near zero bias"). The light pulses amplitude will be kept constant by the slow average power closed loop control with the monitor.

In opposite to method A modulation below threshold and switch on delay will occur in the high temperature region

C improves B by keeping the bias current near the threshold by using a temperature controlled circuit. This will save modulation current at high temperature. For realising method C a temperature measurement as near as possible on the laser case is needed. For example a temperature dependent resistor which meets the temperature behaviour of the laser threshold as well as possible can be used.

D is similar C. A temperature dependent resistor which meets the temperature behaviour of the laser slope as well as possible can be used.

For both methods C and D the thermal model of the laser (Appnote ... can be used for designing the temperature dependent resistor.

E: If a very high quality eye diagram is needed a closed loop control with monitor for bias current and modulation current has to be installed (E).

Numerous and sophisticated methods for such two loop control circuits have been developed, which measure the gradient of the characteristic with the aid of a superimposed pilot tone and control the modulation current accordingly.

Using a fast monitor photodiode as in Siemens lasers it is possible to measure and regulate the pulse amplitude directly. At high frequency (several 100 MHz) electrical crosstalk between laser and monitor photodiode will influence the control loop!

F and G:

If threshold and slope would have the same temperature characteristics it would be possible to use a slow average power closed loop control with the monitorphotodiode and couple bias control and modulation control directly (with a suitable proportionality). In practice the temperature coefficient of the threshold is greater than the temperature coefficient of the slope, as can seen in the application note “enhanced thermal model for laserdiodes”.

In order to adapt the temperature coefficients with a parallel resistor to the laserdiode the temperature coefficient effective temperature coefficient for the laserdiode may be decreased. The disadvantage of this is an increased power consumption. The other method to increased the effective temperature coefficient of the slope by using a unregulated part of the modulation current avoids additional power consumption.

Effort for adjusting the control circuit

Two fundamental parameters are given to each laser: Monitor current for a defined output power (example Imon for 1 mW) and power slope (mW/A).

Therefore normally to positions (average outpower according Imon and optimum modulation according slope) have to be adjusted. Only the method E by using pilot control may be able to find out the optimum modulation current automatically.

Recommended circuit design example

Siemens proposes for low speed applications to use a circuit as shown in **Figure 4**. The laser should work with a bias current lower than the threshold at the minimum temperature. The average light power has to be kept constant by slow average power closed loop control with the monitor influencing the modulation current.

In order to reduce the maximum needed modulation current at the maximum temperature (end of life) it is possible to realise a temperature controlled bias current. The voltage on the basis of T1 has to follow the temperature characteristic of the threshold or has to be directly coupled with the modulation current control (method F and G).

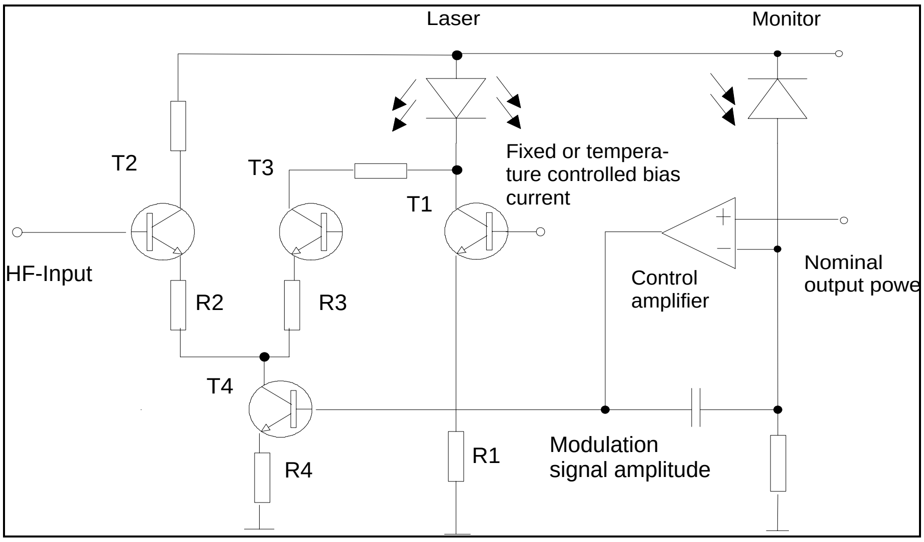

Figure 3
Principal function of the recommended power regulation circuit with one control loop

Figure 4 shows a 155 Mbit/s eye diagram measured with a 300 MHz lowpass receiver under the following conditions:

I_o	threshold current at 25 °C	14	mA
S_o	power slope at 25 °C	176	mW/A
Bias current		1	mA
Modulation current (peak)		40	mA
Optical peak power		5	mW

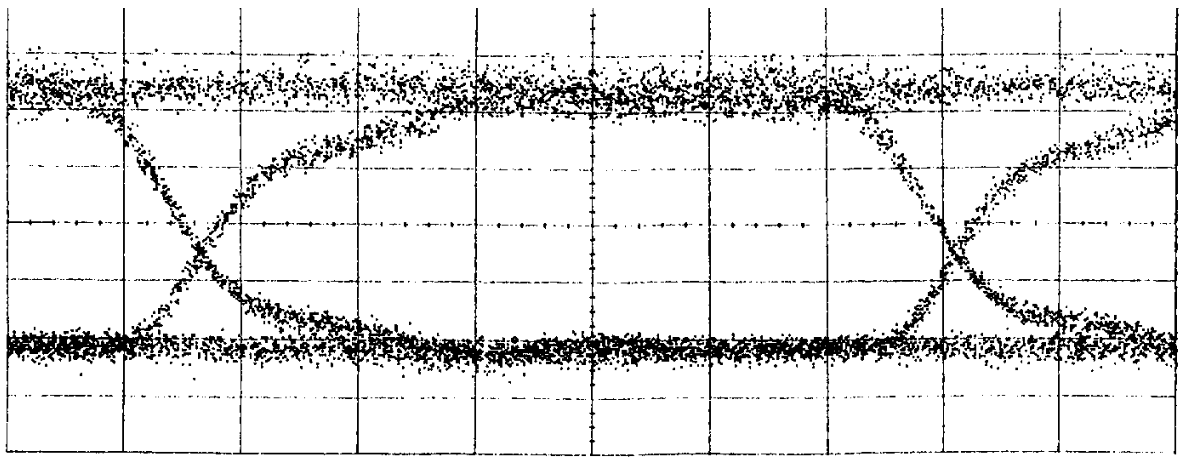

Figure 4
Eye diagram of the optical output (155 Mbit/s measured with a 300 MHz lowpass, time scale 1 ns/ division)

It is important to use a modulation current clearly higher than the threshold current. Therefore, in systems which don't need the high power, modules with small coupling efficiency (low power modules) should be used.