POWER SUPPLY AND CURRENT MODULATION CIRCUITS FOR SEMICONDUCTOR LASERS

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Abstract Design and construction of a stable current supply with protection circuits are described. The reported circuit provides a high-stable and high-level current variable from 0.5 -1.2 A with the protection circuits to prevent overload current, voltage and off-range temperature operation. A detailed analysis of the circuit parameters is given and the time behaviors of the load voltage/current and shut-off voltage/current are presented. Theoretical analysis shows a turn-on time of about 20 ns for the load current and a shut-off time of about 150 ns. The proposed scheme is verified both by simulation and by constructing a prototype. The prototype version of this circuit shows a good stability in load current, and the laser diode temperature can be monitored with an accuracy of about 1 degree. In addition, design and analysis of the current modulator and switching circuits for laser diodes are reported. Modulation process and different modulation techniques are explained in detail. Drive circuits for positive and negative intensity modulation are presented. Transient analysis for the proposed drivers is performed by using PSPICE software and the results are reported here. Evaluation of the results indicates that the reported modulators can be used successfully for direct current modulations.

Key Words Power Supply, Modulation, Current, Voltage, Semiconductor Laser

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INTRODUCTION

In laser diode operation, the power supply current has an important role in the stability, mode spectra, and the laser output power. To control this parameter precisely there are two methods of using an internal monitor diode or external feedback circuitry. In internal method, a built in monitor diode is situated close to a laser diode in a single package in order to control the laser diode operation [1]. Although such a combination works nicely, its fabrication is more complicated and its cost is higher than a single laser diode. An alternative method is to control the supply current with an external feedback circuitry. A detailed description of such a system with special protection features is presented in this report.

The reported power supply is suitable for driving laser diodes, specially those, which require high level stable currents. For pulsed operation of the laser diodes, a pulse generator is usually used to drive the laser. With some modifications, the pulsed operation of laser diodes or other delicate devices sensitive to current regulation would be possible [2]. The key point in this mode of operation is to provide a high current level (0.1-5 A) with pulse width of varying from 2 to 10 ns. Another application of such a circuit may be for the amplitude mode switching for modulation of laser diodes.

The reported module consists of a current control unit, incorporating a current regulating circuit, power supply circuit, and fault sensing and indicating circuits. This report begins with a description of the laser diode driver circuit and a detailed computer analysis of the load with shot-off currents.

Fiber-Optic communication systems have shown a great potential to be used for the case of high rate data communications [3]. Due to special properties such as higher carrier frequency with respect to microwave, this type of transmission line has offered several advantages over the conventional systems. Transmission of information via such an optical system requires a modulator, an optical source, a fiber transmission line, a photodetector, and a demodulator.

Modulation in lightwave communication refers to the process by which information is impressed on an optical carrier to be transmitted by the fiber. Demodulation is the reverse process by which information is extracted from the carrier at the receiver end of the fiber. Optical communication systems, therefore, need some kind of modulators and often digital modulation scheme is used for this purpose. Optical frequencies are high and, hence, permits high modulation frequencies and thus high data rates.

Modulation of the laser diodes can be accomplished directly or indirectly by using an external modulator. The amplitude, frequency , or phase of an optical waveform can be changed to represent the information to be transmitted. Amplitude modulation, the simplest method, is the modulation of the light source output power. Direct modulation of the output power of a diode can be achieved by varying the current through the device [4,5]. Design and analysis of such a current modulator is the focus of this study.

It is possible to use either external or internal means for laser diode modulation. External techniques such as electro- or acousto-optic modulators can be used for optical-signal modulation and switching. There are several different types of electro-optic modulators and switches that can be fabricated as bulk or in a single-waveguide structure. Intensity, frequency, phase, or polarization modulation of the optical-signal can be accomplished by these devices at high frequencies [6].

The acousto-optic effect can also be used to change the index variation in a periodic way in order to produce a grating pattern in the index profile. Bragg-Type and Raman-Nath-Type modulators have been developed for optical modulation and switching purposes [6].

So far, we have described the indirect modulation schemes. However, it is possible to internally modulate the output light of a semiconductor laser. This can be done by either the current flow through the device or some internal cavity parameter. Such direct modulation of the laser output has the advantage of simplicity, and with some care, potential for high frequency operation.

The output of a laser diode can be made to vary in response to changes within laser cavity, so as to produce amplitude modulation (AM), frequency modulation (FM), or pulse modulation (PM) by controlling the current flow through the diode. However, other parameters, such as the dielectric constraint or absorptivity of the laser diode material can be used to produce such modulations.

Pulse modulation is practically convenient in laser diodes because of their very short turn-on and turn-off rise and fall times (typically a few hundred picoseconds for DH stripe geometry lasers). It is therefore possible to produce subnanosecond pulses at repetition rate of 30 MHz, which can transmit a data rate of about 150 Mbit/s. However, with particular biasing, the initial delay between the application of the current pulse and the emission of the laser light pulse must be minimized for high speed operation.

LASER DIODE DRIVERS

When laser diodes were first developed, the threshold current was of the order of 0.5 A or larger, but recent developments in design and construction of such devices have resulted in a considerable decrease in this current. At present, the threshold current for GaAs/GaAlAs DH lasers typically ranges from 30 to 100 mA. This reduction in the threshold current has simplified the drive circuit for such lasers and has reduced the power dissipation of the laser diode.

Although the driver circut for laser diodes such as GaAs/GaAlAs DH is simple, the design of a high power current supply requires more attention, which is the focus of this work. Recently, the introduction of lead-salt semiconductors such as PbSrS has provided the possibility of fabricating IV-VI compound laser diodes. This type of device can operate at room temperature and cover a wide range of IR spectrum (6-8 mm). However, the threshold current versus temperature for such laser diodes shows a range of 0.1 A (at 50 K) to 1A (at 200 K) and even higher for room temperature. For example, for a PbSrS DH laser with SrS concentration of 33%, the threshold current is about 1.25 A in comparison to 0.25 A for PbS DH laser [7,8].

In practice, most of laser diode driver circuits are designed to stabilize the laser operating current to minimize the offset temperature. This means that the laser optical output remains unaffected by any temperature change. One practical solution is the use of a monitor photodiode to stabilize the laser output power. This is accomplished via a feedback by temperature circuit and the optical output controls the drive circuitry through the monitoring photodiode [9].

Another stabilization method often used, employs a thermistor as well as a photodiode in the laser diode package and the current is directly or indirectly controlled by this thermistor. By connecting the thermistor in series with the laser diode, its current can be made to track the threshold current. An increase in temperature tends to increase the threshold current and since the thermistor resistance decreases with temperature, it causes the diode current to increase, tracing the change in the threshold current [10].

As mentioned before, the laser diode is sensitive to temperature variations and output power varies with temperature. Therefore, it is advisable to keep power constant or at least constantly to monitor output power. To combat this fluctuation, the manufacturers include a monitor photodiode or photo diode/thermistor in the laser diode package. However, some laser diodes like the one we had available do not have such internal monitoring circuits, so there was a need for designing a stable current supply.

Considering this fact, we have designed a stable power supply with protection circuits which includes a temperature sensor to control the laser diode operating condition. The fault sensing and indicating circuits insure the safe operation of the laser diode at a proper temperature range. In the case of any fault the diode current is cut off quickly and an indicator

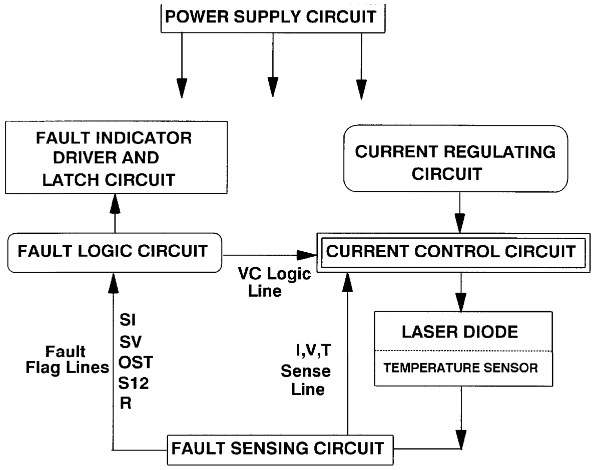

Figure 1. Block diagram for the proposed current supply system.

CIRCUIT DESCRIPTION

shows the type of fault occured in the circuit. The general structure of the reported drive system is simple [11], so a brief description of the circuit is given here. Instead, we emphasize the parametric analysis of the circuit and the results which can be helpful in optimizing the design and operation of such circuit. The flowchart and the operation procedures are presented in Figure 1. It includes current control and regulating circuits; a power supply circuit, fault sensing and display circuits.

(a) Current Control Circuit The current control unit consists of two parts: a feedback current regulator circuit and a current switching circuit. The schematic of the current control circuit is given in Figure 2. The major components of the feedback current regulator are: a darlington transistor, Q 1, operational amplifiers U2, U3, U4, and U5. The voltage across the sampling resistor (R34®®R35) after amplification by instrument amplifier produces a voltage, which is very close to the reference voltage.

The reference voltage is provided by a pin programable precision voltage reference U1 and a potentiometer R3 which defines the current level in this process. The reference voltage through U1 is feeded to U2. In this way the operating voltage across the resistor (R34®®R35) is compared with the reference voltage. In case of any difference, U2 output is set at high level and Q1 keeps the current so as to be regulated by this scheme.

The operation of the regulator feedback loop is such that the product of the resistance value of the sampling resistor (R34®®R35) times the Q1 emitter current produces the operating voltage. This voltage is then amplified by the instrument amplifier and the amplified voltage is applied to the inverting input of U3 which the noninverting input of U3 is devoted to the reference voltage. This process shows the regulation of the current through the emitter of Q1. In Figure 2, capacitor C3 reduces the a. c. gain of the base-emitter of the Q1 in order to prevent oscillations and to stabilize the current gain. Capacitor C2 together with the shunt resistor R4 increases the a. c. gain of the feedback regulator circuit. In other words, the combination of these elements speeds up the operation of Q1 in regulating the current.

The regulated current marked as node A in Figure 2 is then transfered to the switching circuit, which is shown in the lower portion of this Figure. By using this part of circuit, the regulated current can be switched through two possible paths. The main components of this circuit: are two MOSFETs Q2, Q3 and the laser diode, D5, as shown in Figure 2. The regulated current can be switched either through Q2 to ground or can be switched through Q3 to the laser diode which is the desired path.

The on/off situation of either of MOSFETs Q2 or Q3 is controlled by their gate voltages and high/low level corresponds to those situation accordingly. As shown in Figure 2, The gate voltage for collector of the inverter Q5 is the input for the Q4 and, therefore, the

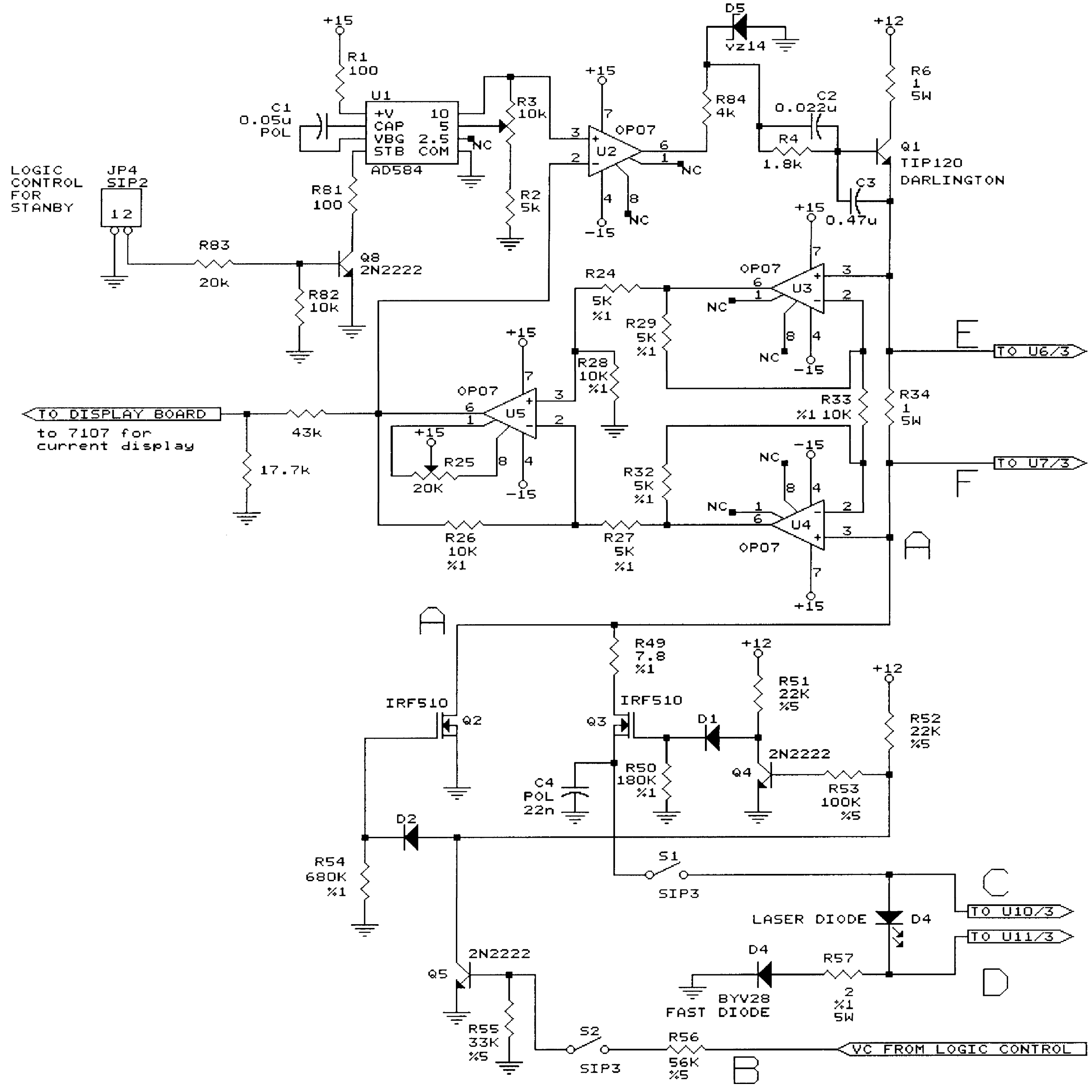

Figure 2. Current control circuit including : a feedback current regulator (upper portion) and a current switching circuit.

operating condition of Q2 after a short period of time is the reverse of Q3. As a result, the regulated current can be switched only through one of those two paths.

The input of the inverter Q5 is controlled by VC from logic control circuit. The required voltage can be supplied when switch S2 is in closed position. When switch S2 is in open position the input to the inverter is low and this causes the switching current to be grounded. Diodes D1 and D2 are considered here to ensure that Q2 and Q3 turn on faster than they turn off. The capacitor C4 is used to prevent undershooting of the regulated current and R49 is a monitoring resistor to control the laser current.

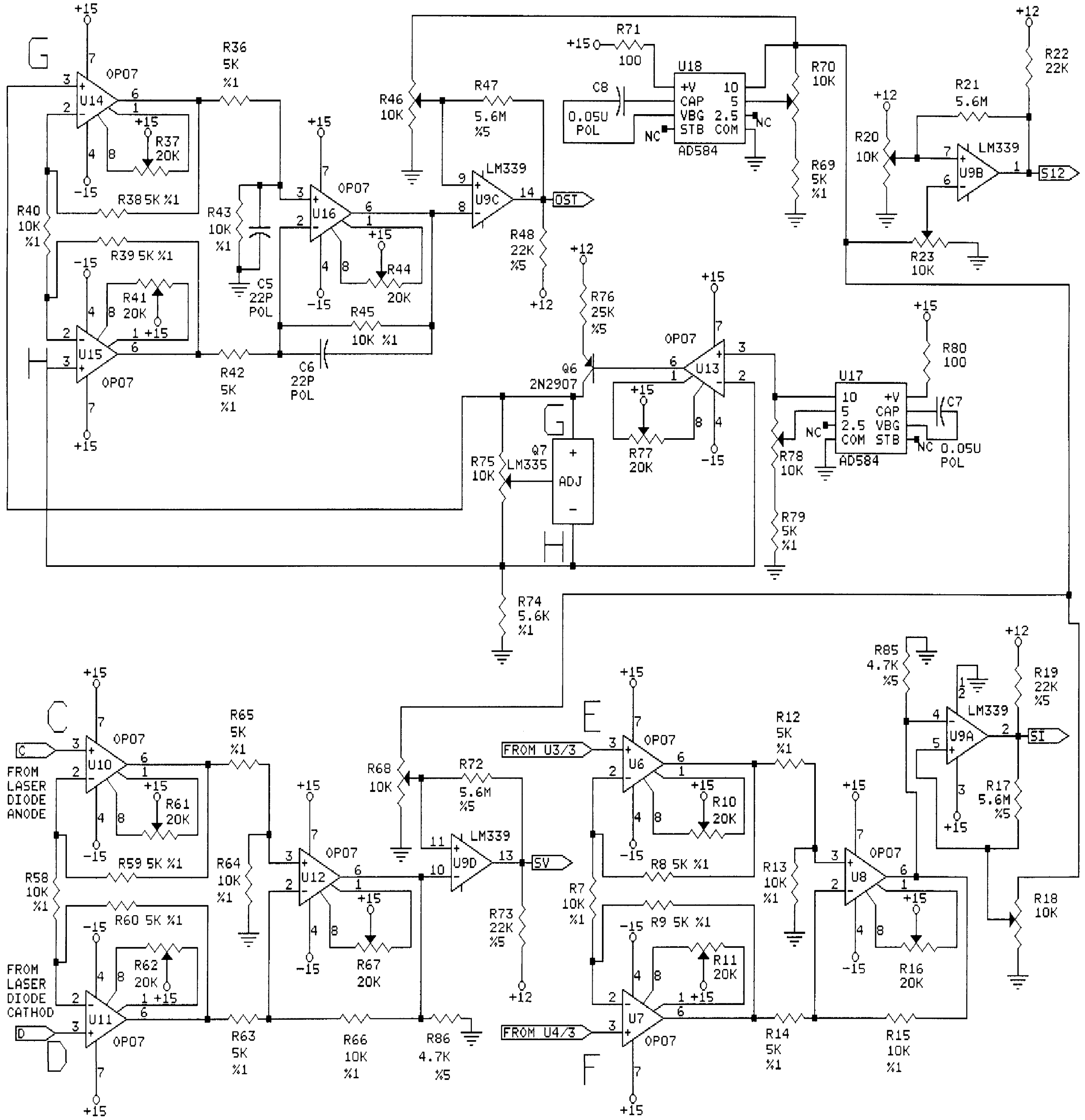

Figure 3. Fault sensing circuit including: high voltage, high current, high temperature faults, and fault sensing for low battery operation.

(b) Fault Sensing Circuit In principle there are four major faults that can be detected by the proposed scheme. These include : (1) high current, (2) high voltage, high temperature faults, and (4) optional low voltage fault for the battery operation. The schematic of this circuit is given in Figure 3.

The high current fault circuit is constructed by the operational amplifiers U6, U7, U8, and the comparator U9A. The amplifiers U6, U7, and U8 provide the instrument amplifier for this circuit. The potentiometer R18 controls the maximum voltage level as well as the reference voltage of U8. This potentiometer determines the reference voltage, which is fed into the positive input of the comparator U9A, as shown in Figure 3, and defines the maximum allowable current or the amount of fault current. As can be seen, the operating voltage (across node E and F in Figure 3) which is the same as voltage on the sampling resistor is fed into the instrument amplifier circuit of Figure 3 (to U6 and U7). The output of this amplifier is given to a Schmitt trigger and the logic value of SI is assigned to this output. This logic line at high situation presents when there is no fault in current passage, but in the case of any fault this line is set at low voltage (zero). The resistor R85 at the input of the instrument amplifier is designed to limit, or omit the cases in which the input switching is doubtfully in a common mode.

The circuitry for high voltage fault detection, which includes a combination of operational amplifiers U10, U11, U12, and a comparator U9D, is also shown in Figure 3. As can be seen, this circuit is similar to the part for the current fault and operates in a similar fashion. The voltage on the laser diode (between nodes C and D in Figure 3) is fed into the instrument amplifier and its output is given to the comparator which is designed as a Schmitt trigger. This output is assigned with a logical value of SV as shown in Figure 3.

If the voltage provided by the amplifier for laser diode is lower than the reference voltage (set by U8), there is no fault, and the logical value of SV is high, but if this voltage is higher than the accepted level, then it is indicated by low SV in the circuit.

The schematic representation of the high temperature detection is given as a part of Figure 3. This part consists of a current source, a temperature sensor, a precise differential amplifier and a comparator as a Schmitt trigger circuit. The temperature sensor used for this purpose is LM335, which should be located close to the laser diode. The amplifier U13, reference voltage of U17 and transistor Q6 provide a precise and controlled current for this sensor. The optimum current for this sensor was found to be in the range of 0.5 mA to 5mA. In this range, the applied voltage is in the range of 2.95 to 3.01 V. For the safe operation of the sensor its current was set (Potentiometer R78) at about 1mA corresponding to a voltage value of 2.98 V.

If the instrument amplifier used in this part of the circuit shows even a low drift due to common mode gain, it will cause an error message for the temperature sensing. The temperature sensor, therefore, must be shielded properly. To complete the circuit, the output of the differential amplifier goes to the negative input of the comparator as a Schmitt trigger, U9C. The potentiometer R49, together with U18 provides an adjustable reference voltage for this comparator. A logical value of OST is assigned to the output of U9C. When there is no temperature fault, this is low, and when there is a fault (high temperature), it moves to a high value.

For common mode rejection gain of the amplifier, matching of (R36, R42) and (R43, R45) pairs is very important. The role of capacitor C5 and C6 in the differential amplifier is to reduce a.c. gain. When there is a big swing in the common mode voltage, the capacitors act like filters, and thus there is no problem of output voltage oscillation.

The optional circuitry for the battery operation, which consists of a comparator U9B as a Schmitt trigger, is also considered in Figure 3. The comparator in this case operates when the voltage is lower than 10.35 V (this minimum voltage is set by the potentiometer R20). The digital value of S12 is assigned to the output of U9B. If the battery voltage is lower than the set

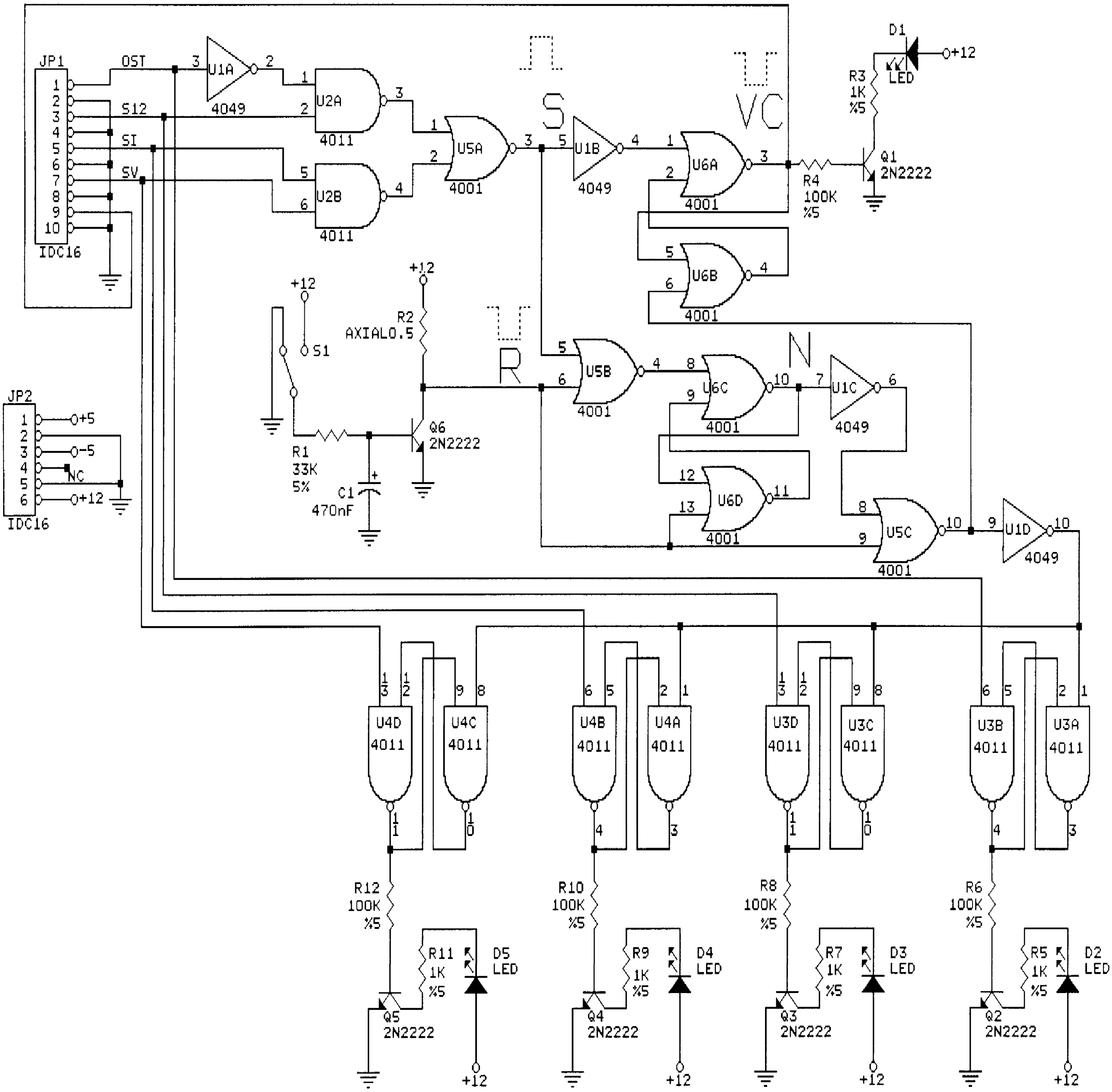

Figure 4. Fault logic circuits and related gates.

value, it is low, and when voltage is high enough, then it is logically high.

(c) Fault Logic Circuit This part uses logical gates, and through the VC line, it controls the current switched through the laser diode as well as voltage, temperature and the low voltage for battery operation. The schematic representation of the circuit for such an operation is displayed in Figure 4. The inputs to the circuit are: SI, SV, OST, and R, which stands for the logical value of RESET. When the reset switch S1 is not pressed, its value is high, and for the pushed position it is considered to be low. The capacitor C1 here prevents unwanted switching of Q6 and for the case of pressed S1, it provides a constant d.c for Q6.

The logic circuit provides the necessary conditions for the operation of the drive circuit. In a case that there is a fault such as high current, the regulated current can not pass through the laser. However, if the fault is corrected, then by pressing the RESET push button the current can passes through the laser diode. As can be seen in Figure 2, if S2 is in position 3, the line is closed and VC is high so the current flows through laser and in a case of any error its value is low and Q2 switches the current to ground.

Fast phenomenon such as electrical spikes may occur quickly, so the logic circuit should operate in due time. We, therefore, have used two latches and NOR gate to verify the VC control line. In this case, VC would not be high unless the RESET switch is pushed down. In order to prevent damaging the drive circuit by pushing the RESET switch many times, a pair of NOR gates is used to limit the RESET process to once. Hence, the reset signal of R at input acts on VC and the operator would not reset the circuit before correcting the fault.

As can be seen in Figure 4, latch circuit and LED drivers indicate the type of error, and when there is no fault, the CURRENT READY led is on. When switch Sl in the switching circuit (Figure 2) is in position 2, the current is passing through the laser diode, but if there is a fault, first the CURRENT READY LED goes off and the corresponding LED for that type of error is on.

(d) Display Circuit The display circuit diagram includes CL 7107 ICs and 7 segments. The load voltage and the temperature are displayed by this part . The 7 segments are used to show the drive current as a four digit number (mA). This unit also shows the sensor temperature as a 3 digit number while the first one from the left is considered for the sign.

(e) Power Supply In order to supply the voltage required for different parts, a power supply circuit is devised. It consists of 3 full bridges, LM 7815, LM 7915, LM 7812, LM7805, LM7905, and LM 7815 components. This circuit supplies the required voltages for driver board, logic board, fan, single supply and optional header for a modulator board.

CURRENT MODULATOR CIRCUITS

For the current modulation of the laser diode, two types of positive (series) and negative (parallel) modulation techniques are considered. Positive modulation uses switching method for which three methods can generally be implemented: current mode switching, saturation mode switching and avalanche mode switching. Since the first method is more reliable, it is used in this work.

The schematic representation of the positive current modulation is given in Figure 2. The modulator circuit consists of two portions: a feedback current regulator and a current switching circuit. The current regulator is shown in the upper portion of Figure 2. Its major components are: a darlington transistor (Q1), operational amplifiers U2, U3, U4, and U5. The voltage across sampling resistor (R34 | | R35) after amplification by instrument amplifier produces a voltage which is very close to the reference voltage.

Although, the described positive modulator works well for low frequencies, its reliability is not very good for high frequency applications. Therefore, a negative modulator is devised, which is more useful for the case of audio/video signal modulation. This circuit uses a MOSFET, Q1, in parallel with the laser diode, D5, as shown in Figure 5. In this case, when an audio or video input signal is provided, the current swings around the operating current level.

Since MOSFET Q1 is parallel with the laser diode, the laser current will be affected by the

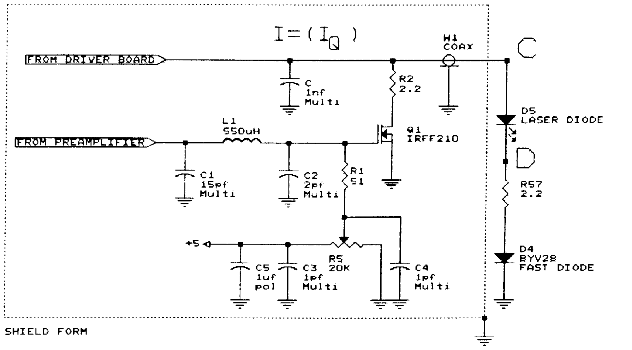

Figure 5. The schematic diagram for the negative current modulating circuit.

Q1 condition. There is a phase difference of about 180 degrees between the input and the drain current of Q1 and ID. So for the peak value of RF signal, the amount of current passing through the laser is minimum. This means that when the input is at its minimum the laser diode current will be the regular current. In other words, by increasing the signal level, the current passing through the laser diode is reduced or modulated.

In this type of modulation, in contrast to positive modulation described before, by increasing the signal level, the laser current is reduced. This phenomenon is referred to as negative modulation. By using the negative modulation technique, the maximum power signal delivered to the laser diode is limited to a certain level which provides a safety factor for the laser operation.

The bias voltage of MOSFET Q1 is controlled by a potentiometer, R2. By using a proper biasing, this kind of circuit provides the necessary conditions for current switching. The input impedance of Q1 is usually high and for obtaining the maximum power from RF signal, an impedance-matching network is considered for this circuit. This circuit as shown in Figure 5 incorporates C1, L1, and C2 for this purpose. The optimum value of each parameter of the network is obtained by using a software analysis.

In view that audio or RF signals have low amplitudes, there is a need for a preamplifier circuit, which is dispalyed in Figure 6. This circuit is built around an amplifier (AD5539), which has an open-loop bandwidth of a bout 1.4 GHz. The maximum swing in the output depends on the voltage supply and for 5V, the value of Vout reaches 1.75 V while Vout is limited to 1.45 V. For this range of operation the values Rx = 470 W and R1 = 1 KW are selected for the present circuit.

CIRCUIT ANALYSIS AND RESULTS

To simulate the current supply circuit, we have used the PSPICE 4 software and the transient analysis for the circuit is reported in this section. It is assumed that Vg applied at point B of Figure 2 is a pulse with the amplitude of 12 V and a pulsewidth of 1.5 ms. A current source, IDD, of 1A d.c is considered to pass at node A to the high current MOSFET devices Q2 and Q3, VDD is assumed to be equal to 12 V for Q3, and Q4, and VDS equal to 11 V. Based on this input parameters different analyses for 2.5 ms are performed and results are reported.

A typical analysis for the current passing through high power MOSFETs Q2 and Q3 , which are shown by ID(M1) and ID(M2), respectively, is displayed in Figure 7. The voltages at the collectors of Q4, V(6), and Q3, V(8) have a time behavior such as shown in the lower part of Figure 7. For a better comparison we have plotted V(6) and V(8) as the input switching voltages for all cases. V(6) has a raisetime of about 100 ns and reaches its peak value, which is about 10.25 V. It stays constant at this voltage level for a period of about 1.25 ms and then goes to zero at a time of about 15 ns. As can be seen in Figure 7, inversely, V(8) for Q3 starts at a voltage of about 10 V and falls down [V(6) is raising at this stage] to zero at a time of about 10 ns, it remains zero for a period

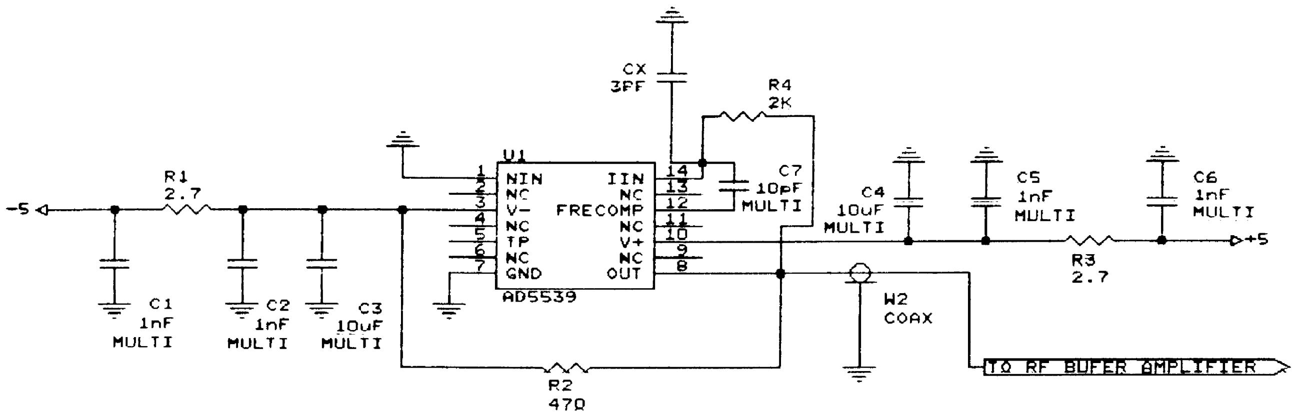

Figure 6. The Schematic diagram for the preamplifier designed for the negative modulator.

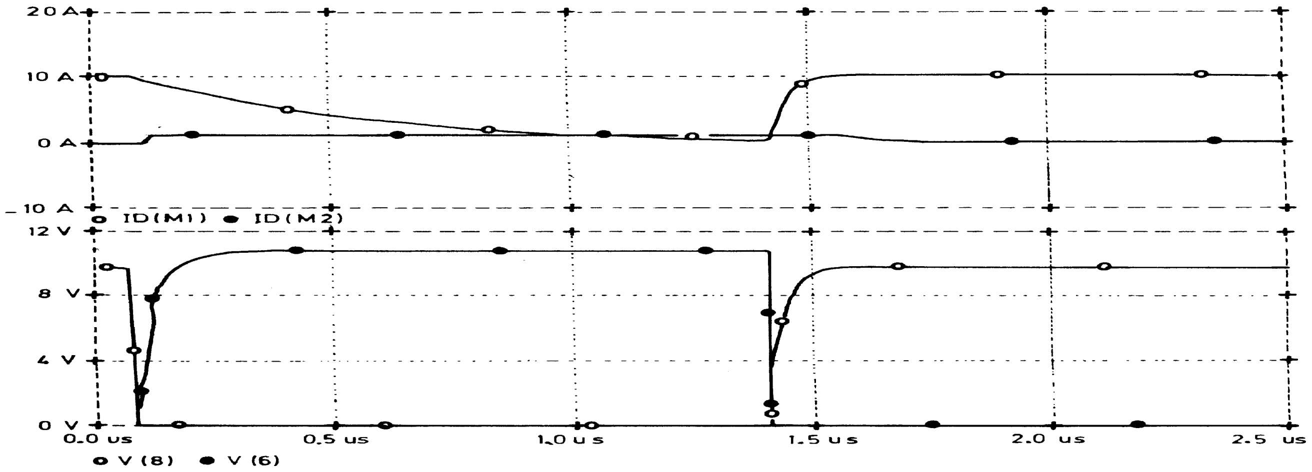

Figure 7. Transient analysis for currents through high current MOSFET devices Q2 and Q3 (upper portion) and lower portion shows the collector voltages for Q4 and Q5, V(6) and V(8), respectively.

of about 1.3 ms until raises again to its initial value.

As can be seen for the MOSFET currents, only one current through one path (normal case Q3) can be switched. The current, ID(M1), starts at 10A level and decrease to zero slowly in a time scale of about 0.7 ms, and raises to 10A again with a quick raisetime of about 60 ns. As discussed before, the purpose of diodes D1, and D2 is to insure that both of the MOSFETs switch into the conducting state more quickly than the off state. This fact is clearly shown here for the normal operation of Q3 and it is true for Q2 in the case of fault occurrence.

In the subsequent study, we have considered the time behavior for the gate- source voltage of Q3 and the gate voltage of Q2. The results show that the voltage difference starts at zero level and quickly (raisetime of about 90 ns) reaches a value of about 5 V and then it stays constant for a time of about 1.5 ms. At this stage, while Q2 gate voltage peaks up, voltage difference is reduced slowly with a time scale of about 0.3 ms to initial zero value. The time variation of Q2 gate voltage is such that it starts from 9.5 V and slowly drops to 3.5 V, and as described, peaks up to about 9.5 V with a raisetime of about 70 ns. This again shows that turn on time for Q2 is much faster than its cut off time. At the same time gate-source voltage

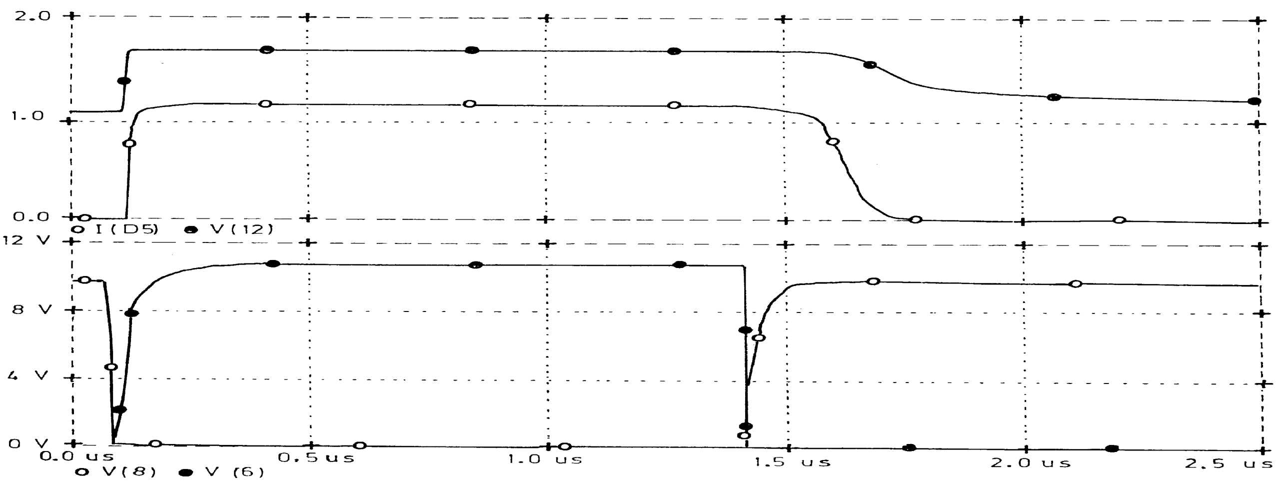

Figure 8. Transient analysis for the laser diode current, I (D5) and load voltage V(12), shown in the upper portion. Lower part shows the usual input voltages to MOSFETs Q2 and Q3.

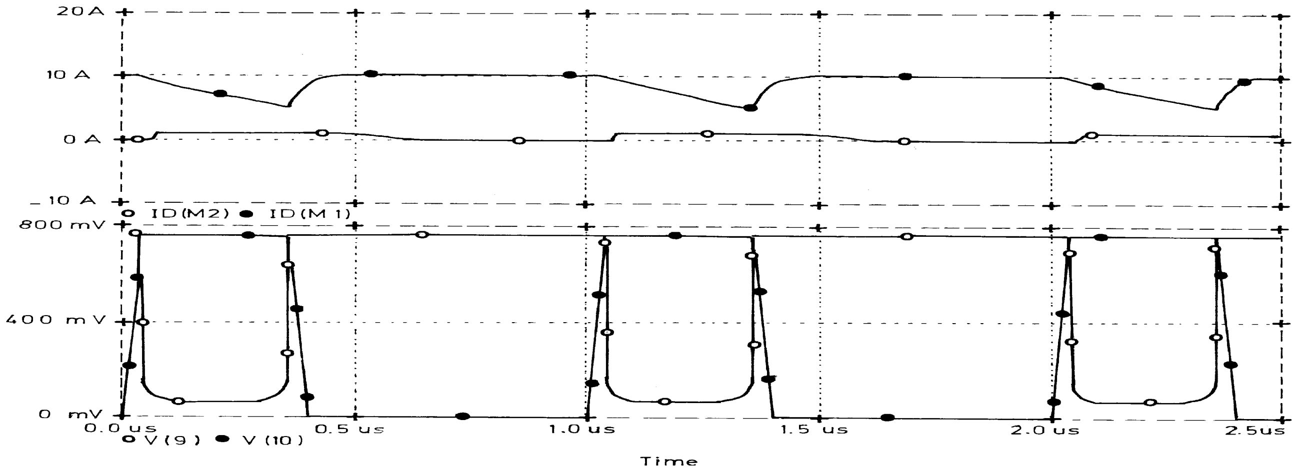

Figure 9. Transient analysis for the current passing through the laser diode, ID(M2), (upper part). The lower portion shows the gate voltages of MOSFETS. V(9) for Q4 and V(10) for Q5 (see Fig.2)

behavior emphasizes the same effect for Q3 operation .

Finally, the important parameters of the laser diode, i.e. load current and voltage are studied and the result is shown in Figure 8. At the switching moment (after about 100 ns), the current through laser diode, I(D5), peaks up from zero value and reaches a value of about 1.2 A with a raisetime of about 20 ns. The current stays at this level for about 1.7ms and then drops to zero with a falltime of about 150 ns, which is slower than its raisetime value. As can be seen in Figure 8, the diode voltage shows a very similar time behavior. It begins to build up from initial value with a raisetime of 20 ns and falls down with a falltime of 150 ns.

Simulation of the modulation circuits was accomplished by using proper softwares runing on P.C. of which the results are reported in this section. First, we present the results for the positive modulation and then we consider the negative modulation circuit. Figure 9 shows the current modulation through the high power MOSFETs Q2 and Q3 (upper portion). The current passing through Q2 is denoted by ID (M1) and through Q3 by ID(M2). As can be seen in Figure 9, the turn on time for these MOSFETs is much shorter that the turn off

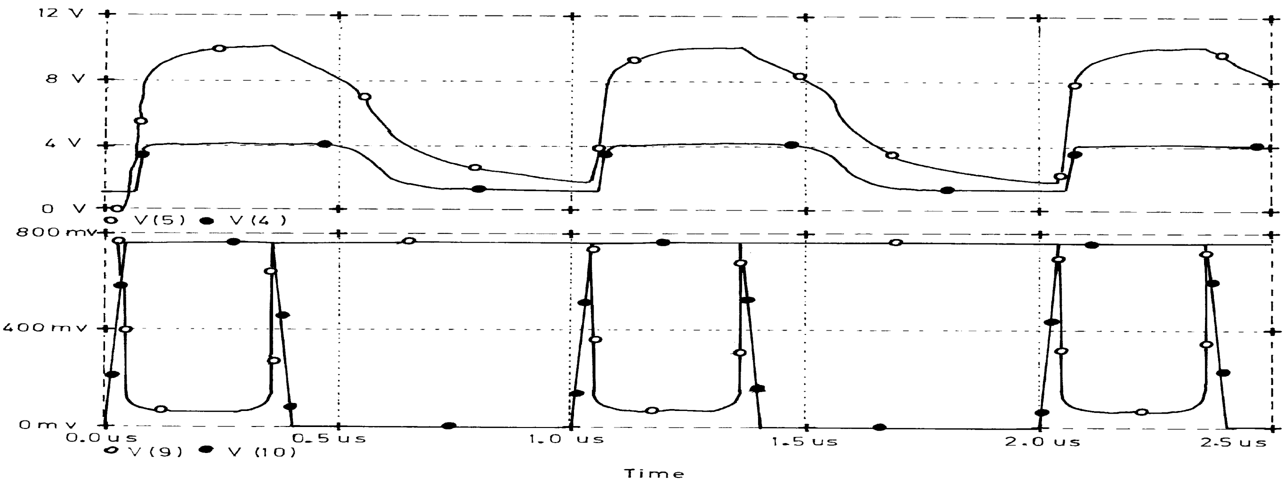

Figure 10. Transient analysis for the drain voltage V(4), and the gate voltage, V(5) of MOSFET Q3 for positive modulation. The lower portion again shows the input gate voltages for MOSFETs.

time. The raisetime of the current is about 150 ns while the fall time is around 300 ns. This verifies the condition that is required for the circuit design.

For a better comparison, the lower portion of Figure 9 dispalys the input voltages for the gate of Q4 and Q5, which are represented by V(9) and V(10), respectively. As can be seen the transient behavior of Q4 and Q5 voltage wave forms is opposite to each other. At the moment that V(9) has high value, V(10) is near the zero and vice versa. Also, There is a good corelation between the gate voltage of Q4 (V(9) waveform), and the switching current through MOSFET Q3, which is shown by ID(M2). A similar argument can be given for the correlation between the gate voltage of Q5 (V(10) and the switching current through MOSFET Q2 that is denoted by ID(M1)). From Figure 9, the on/off state of the inverters Q4 and Q5 and as result conducting state of MOSFETs Q2 and Q3 can be recognized.

Another point is that at normal condition, current switching is through the laser diode by Q3, but in case of any fault, Q2 conducts and provides the safe operation of the laser diode, which is relatively an expensive element. In principle, four major faults include high voltage, high current, high temperature and the low battery voltage fault for the case of battery operation.

Figure 10 shows the analysis for the drain voltage, V(4) and the gate voltage V(5), of MOSFET Q3 which switches the laser diode (upper portion). The lower portion of Figure 5 shows the gate voltage of inverters Q4 and Q5 acting as input to the high power MOSFETs. The voltage at the drain of Q3 which is denoted by V(4) shows a similar time behavior as the gate voltage V(5) with the exception that V(5) has higher voltage level as can be seen in Figure 10. Considering Figure 10, the risetime for both of voltages is shorter than the falltime values, which indicates a quicker turn on for Q3 in comparison with its turn off time. Since V(5) acts like input voltage for the MOSFET Q3, Figure 10 shows that any increase in the input voltage level will cause an increase in the voltage delivered to the laser diode which shows the positive modulation.

A simulation program was performed for the parallel modulation circuit of Figure 5, the result of which is displayed in Figure 11. The upper part of Figure 11 shows the frequency

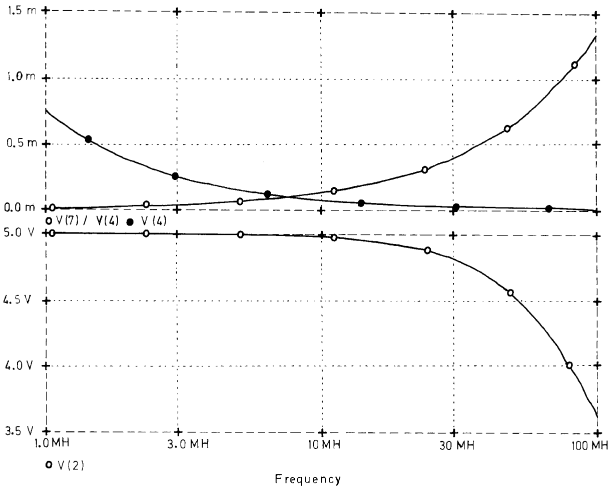

Figure 11. The Frequency dependence of the preamplifier, V(2), is shown at the lower part. The upper portion shows the frequency dependence of the negative modulator gain V(7)/V(4) and the gate voltage of MOSFET Q1 (see Fig. 5) as indicated by V(4).

dependence of the input voltage and the gain factor. The input or the gate voltage for the MOSFET Q1 in Figure 5, represented by V(2) and V(7), denotes the source node for Q1. The ratio V(7)/V(4) shows the gain for the circuit, which is displayed as a function of the frequency. The results show the frequency variation of the gain and the gate voltage. As can be seen in Figure 11, the gain curve shows an increase by increasing frequency while the gate voltage, V(4) shows decrease by an increase in the frequency.

For a better comparison, the frequency dependence of the input voltage V(2) is plotted in the lower portion of Figure 11. This curve shows the frequency characteristic curve for V(2) and the pole frequency can be seen in Figure 11. At frequency of about 30 MHz, there is a fall down in the V(2) which,defines the operating frequency for the input voltage.

CONCLUSION

An important parameter for a laser diode operation is its threshold current and thus a requirement for a drive circuit to provide such a stable pump current above its threshold. We have designed a stable power supply with protection circuits which uses a temperature sensor to check the laser diode working condition. In comparison with other current supplies it has the advantage of having a variable load current which, provides a good means to study the output power versus current characteristic curve of a laser diode [12].

By simulation of the current circuit, the time behavior of the proposed switching circuit was verified, which was important for the construction of this module. The transient analysis shows a raisetime of about 20ns for the turn on current and a falltime of about 150 ns, which is a good indication for the proposed circuit. Our future goal is to check the operation of the prototype version and perform some experiments with the laser diodes.

For modulation, we can conclude that a simple technique for impressing a signal on the output of a laser diode is by current modulation [12]. Considering this view, modulators to drive the laser current have been described. The general from of the direct modulation for positive and negative modulations is described in this study. Higher modulation frequency can be achieved by using the negative modulation circuit. Intensity modulators can also be used as remote modulators in local distribution systems experiments. In spite of simplicity of the direct current modulation, there are some limitations that need to be mentioned here.

Direct current modulation restricts the maximum achievable frequencies to a few GHz [10,13]. Furthermore, with most injection lasers, high speed current modulation also creates undesired wavelength modulation, which imposes problems for systems employing wavelength division multiplexing.

Directly modulated lasers, even

single-frequency distributed feedback lasers, exhabit a change in the output wavelength as the gain is turned on and off. This chirp together with fiber dispersion causes pulse spreading which can limit either the length or bandwidth of lightwave transmission system. This chirp can be overcome by using external modulators.

For high frequencies electro- and acousto-optic modulators have been reported [10]. Also, important waveguide modulators based upon interferometry, which employes optical phase shifting have been developed [14-16]. In coherent lightwave systems, phase modulation encoding offers receiver sensitivity advantage over other techniques such as intensity or frequency modulation.

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