APPLICATION NOTE

AN1122

NE5300: A 50Mb/s - 100Mb/s LED driver for fiber optic communication

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Philips
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INTRODUCTION

The virtues of fiber optic data communications have been discussed earlier in great detail in several publications. This applications brief will address the transmitter aspect of the fiber optic system, specifically the LED driver with a TTL interface. Since most TTL systems are limited to 50Mb/s (NRZ) data rates, the main focus of this application brief will be on the same data rate. However, enough applications information will be given to tailor the system performance to any data rate within the frequency limits of the devices as well as some performance results at a higher data rate.

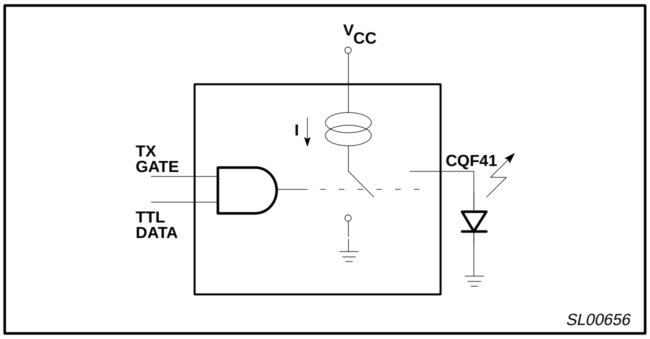

Figure 1. Simplified Block Diagram of the Transmitter

SYSTEM REQUIREMENT

A simplified block diagram of the transmitter is shown in Figure 1. It depicts a current source driving the anode of an LED when the input data is a logic HIGH and switched to ground when the input data is a logic LOW. It also shows a Tx Gate which enables the transmitter when asserted HIGH . This is a very simplistic ! diagram, but later on some of the major issues regarding the design of the transmitter will be discussed in detail. In designing the transmitter several parameters should be considered, viz. optical rise time, optical fall time, optical pulsewidth distortion at the output, optical power output, optical peaking, optical overshoots and undershoots, etc. It should also be noted that an LED is a non-linear device with non-uniform impedance and non-linear transfer characteristics. Due to these characteristics the LEDs are harder to turn off than to . turn on and the phenomenon commonly associated with the difficulty in turning-off the LED is referred to as the long-tailed response of an LED. All these characteristics of the LED necessitate a driver circuit which is capable of delivering more than 60mA of current into a low impedance LED with extremely fast electrical rise and fall time.

TRANSMITTER DESIGN

Reviewing the specifications of NE5300 indicates that it has several desirable characteristics which make it suitable as an LED driver with TTL interface. The totem pole output on N E5300 is capable of sourcing >60mA and sinking,120mA of current from the low impedance load. The electrical rise and fall times are less than 2ns and the t_{PLH} and t_{PHL} are fairly matched. The NE5300 from Philips Semiconductors has several attributes which make it suitable for this application. At V_O = 1.5V, the output resistance is about 23Ω. The slope of the sourcing and sinking currents extended to zero output current switched between the supply rails is very linear which improves the incident wave switching performance. The unique design of the totem pole output eliminates output current spiking or current feedthrough. The NE5300 also has a patented low impedance voltage reference (LIVR) for input speed up and output noise immunity improvement. There is also a patented active pull-off (APO) circuit consisting of a dynamic base discharge and quiescent pull-off network for the output pull-down transistor. This network eliminates any totem pole feedthrough currents.

The complete schematic of the LED driver is shown in Figure 2. The pull-up transistor of the totem pole output is used to turn on the LED and the pull-down transistor is used to turn off the LED. The lower impedance and current handling capability of the saturated pull-down transistor is used as an effective method of transferring the charge from the LED's anode to ground as its dynamic resistance increases during turn-off. The slightly higher output impedance of the pull-up stage ensures that the LED is not over peaked during the less difficult turn-on transition. This asymmetric current handling capability of the output stage with its variable impedance substantially reduces the pulse width distortion and long-tailed response. As the signal propagates through the NE5300, each transition passes through the high-to-low and low-to-high transition once, normalizing the total propagation delay through the circuit. the t_{PLH} and t_{PHL} for the entire system are equal and thus the duty cycle distortion is reduced.

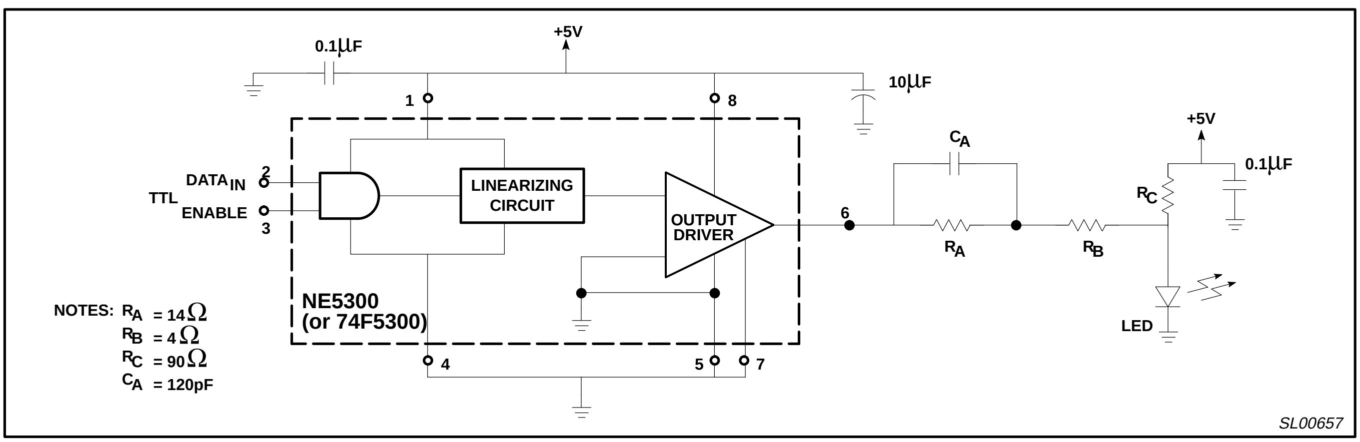

Figure 2. Complete Schematic of the 50Mb/s LED Driver

In order to further improve the optical performance, pre-biasing and drive current peaking, or pre-charging, techniques are used. Pre-biasing is needed to apply a small amount of current to the LED when it is in the off state. This pre-bias current prevents the junction and parasitic capacitances from discharging completely when the LED is in the off state and reduces the amount of charge that the driver must transfer to turn the LED on again. Drive current peaking, or pre-charging, refers to momentary increase in the LED forward current that is provided by the totem pole output stage during the rising and falling edges of the current pulses that are used to modulate the LED. If the time constant of the pre-charging circuit is approximately equal to the minority carriers lifetime of the LED used, then this momentary increase in the current will improve the optical rise time and fall time of the LED without causing excessive ringing in the optical pulses. Overshoot and undershoot in the transmitter optical output, which result due to excessive LED peaking, can combine with noise at the fiber optic receiver and cause errors if they cross the decision threshold of the comparator at the receiver. Excessive peaking during the turn off transition could cause the LED to become reverse biased and degrade the turn on time. The resistors R_A, R_B and R_C and the capacitor C_A are used for the pre-biasing and pre-charging of the LED. Basic circuit analysis techniques can be employed to define the equations for these components. The values of these components can be calculated using the following equations:

$$R_C = \frac{(V_{CC} - V_{FON})}{I_{FON}} + 3.2\,\frac{(V_{CC} - V_{FON - 1.4})}{I_{FON}} + \qquad \text{Equation 1.}$$

where V_{FON} = Forward ON voltage of the LED and I_{FON} = Forward ON current of the LED at V_{FON}

$$R_O = \frac{(R_C - 32)}{3.2} \qquad \text{Equation 2.}$$

where $R_O = R_A + R_B$ Equation 3.

$$R_A = \frac{R_O + 10}{2}$$

$$R_B = R_A - 10 \qquad \text{Equation 4.}$$

$$C_A = \frac{2ns}{R_A} \qquad \text{Equation 5.}$$

CALCULATIONS

The schematic shown in Figure 2 was tried with several different LEDs and a listing of these LEDs in given at the end of the applications brief. The Philips LED CQF41 will be considered here as an example for the calculations. (The CQF40/41 is included in this volume.) From the transfer characteristics of CQF41 it is seen that V_{FON} = 1.8V at 100mA and the LED has maximum power output of 0.8mW at 100mA. Using these values of V_{FON} and I_{FON} in Equation 1, $R_C = 90\Omega$. Using Equations 2, 3, 4 and 5 the values of $R_O = 18\Omega$, $R_A = 14\Omega$, $R_B = 4\Omega$ and C_A = 120pF. These values were used in the applications board and the following results are discussed.

RESULTS

The printed circuit board layout for the transmitter is shown in Figure 3 and the test and measurement set-up for the applications characterization is shown in Figure 4. Figure 5 shows the optical output signal for a 50Mb/s 1-0 alternating pattern. The fiber optic link is about 0.5 meters long. The fiber type is 62.5/125μm with sr™ connectors at each end. The losses due to the connectors are about 0.5dB. It can be seen that the peak-to-peak optical output power is about 82.5μW. The rise time is 3.253ns and the fall time is 3.701ns. The pulse- width is 19.18ns, so the pulsewidth distortion is about 4.1%. The performance at 100Mb/s shown in Figure 6 depicts a rise time of 3.496ns and a fall time of 3.455ns. This yields a pulsewidth distortion of 9.2% for a pulsewidth of 9.079ns. A 50Mb/s NRZ eye pattern with a data dependent jitter of about 300ps is shown in Figure 7.

Significant improvements in the performance of the system were due to the passive components and the NE5300 being in surface mountable form on the printed circuit board. The connecting traces on the printed circuit board have also been shortened to reduce any parasitic inductances. A higher speed LED can be used to further improve the performance of the system by providing faster rise and fall times and also to minimize the pulsewidth distortion.

CONCLUSION

A 50Mb/s TTL input fiber optic transmitter was explained in detail. A complete schematic was given with its printed circuit board layout. The results obtained from this board were illustrated. The performance was given at 50Mb/s and results showing the capability of the NE5300 at a higher data rate (100Mb/s) was also shown. Suggestions for further improvement were included. APPENDIX

The following LEDs have been tested with the given transmitter design. The selection of the LEDs is left to individual applications requirements. Some devices have higher power output, but lower data rates; others have lower power but are capable of higher data rates.

APPENDIX

The following LEDs have been tested with the given transmitter design. The selection of the LEDs is left to individual applications requirements. Some devices have higher power output, but lower data rates; others have lower power, but are capable of higher data rates.

LED	Manufacturer
CQF24	Philips / Amperex
CQF30	Philips / Amperex
CQF31	Philips / Amperex
CQF40	Philips / Amperex
CQF41	Philips / Amperex
CQF42	Philips / Amperex

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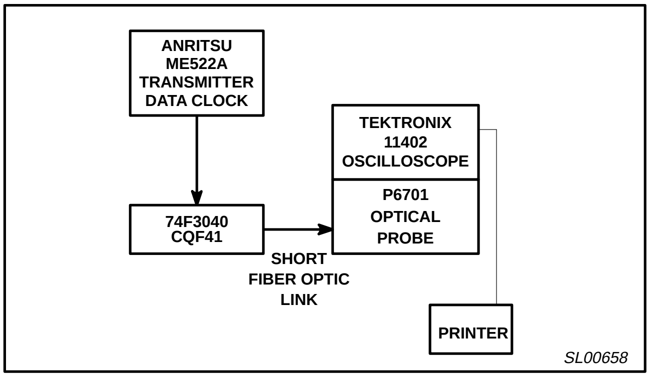
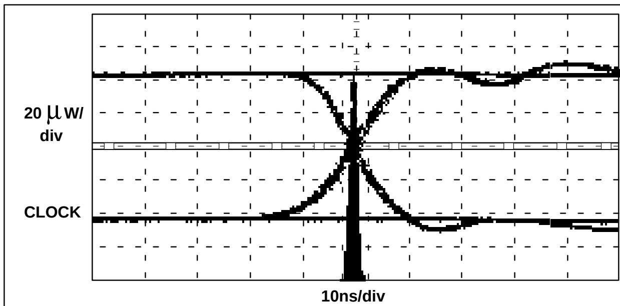


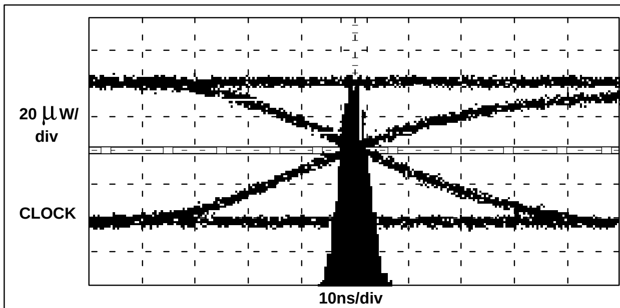
Figure 3. Test Figure



Rise	Fall	Frequency	Main Size 5ns/div	
3.469ns	3.455ns	50.02MHz	Main Pos –20.5ns	
Width	Peak–Peak	RMS	Remove Wfm 2	Pan/ Zoom
9.079ns	84.77µ W	52.07µ W	Avg(L2) Main	Off

SL00659

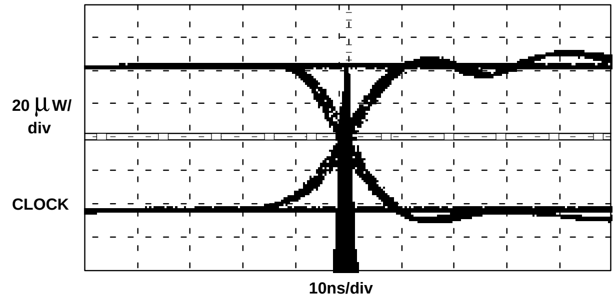
Figure 4.



Rise	Fall	Frequency	Main Size 5ns/div	
3.469ns	3.455ns	50.02MHz	Main Pos –20.5ns	
Width	Peak–Peak	RMS	Remove Wfm 2	Pan/ Zoom
9.079ns	84.77µ W	52.07µ W	Avg(L2) Main	Off

SL00660

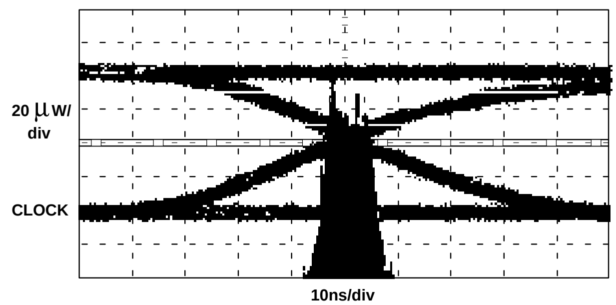
Figure 5.



Rise	Fall	Frequency	Main Size 5ns/div	
3.469ns	3.455ns	50.02MHz	Main Pos –20.5ns	
Width	Peak–Peak	RMS	Remove Wfm 2	Pan/ Zoom
9.079ns	84.77µ W	52.07µ W	Avg(L2) Main	Off

SL00661

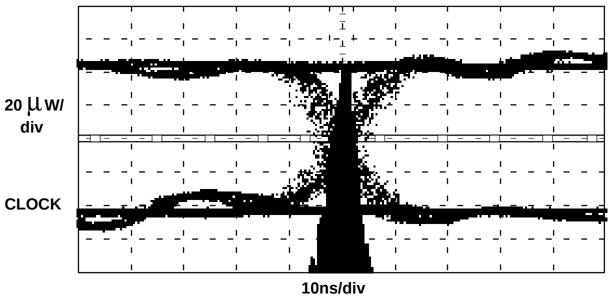
Figure 6.



Rise	Fall	Frequency	Main Size 5ns/div	
3.469ns	3.455ns	50.02MHz	Main Pos –20.5ns	
Width	Peak–Peak	RMS	Remove Wfm 2	Pan/ Zoom
9.079ns	84.77µ W	52.07µ W	Avg(L2) Main	Off

SL00662

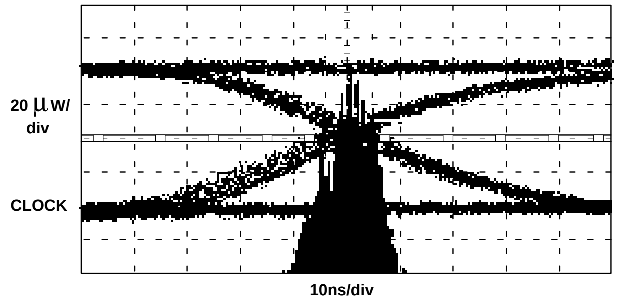
Figure 7.



Rise	Fall	Frequency	Main Size 5ns/div	
3.469ns	3.455ns	50.02MHz	Main Pos –20.5ns	
Width	**Peak–Peak**	**RMS**	**Remove Wfm 2**	**Pan/ Zoom**
9.079ns	84.77µW	52.07µW	Avg(L2) Main	Off

SL00663

Figure 8.



Rise	Fall	Frequency	Main Size 5ns/div	
3.469ns	3.455ns	50.02MHz	Main Pos –20.5ns	
Width	**Peak–Peak**	**RMS**	**Remove Wfm 2**	**Pan/ Zoom**
9.079ns	84.77µW	52.07µW	Avg(L2) Main	Off

SL00664

Figure 9.