# Optimizing the Resolution of Laser Driver Current Settings Using a Linear Digital Potentiometer

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## 1  Introduction

Digital potentiometers are well accepted in fiber optic module manufacturing for setting the transmitter's application dependent variables such as average optical transmit power, and extinction ratio.

This application note provides guidelines for optimizing the current setting resolution for the MAX3735 (2.7Gbps SFP laser driver), when interfaced with the DS1858 SFF-8472 digital diagnostic monitoring device.

The optimization of the current setting resolution is directly related to yield optimization in fiber optic module manufacturing.

## 2  Definition of Current Setting Resolution

The DS1858 provides two 50kΩ resistors with 8bit wide resistor value setting registers. Thus the resistor value can be adjusted in 256 linear steps in respect to the full scale of 50kΩ. These digital resistors are used to set a modulation current of the MAX3735 (10mA up to 85mA) as well as an average optical power through the bias current of the MAX3735 (1mA up to 100mA).

The setting resolution defines the percentage of the resistor value change between two adjacent digital resistor positions.

$$n = [1, 256]$$

$$R_{dig}[n] = 50k\Omega * \frac{n}{256}$$

$$Setting\_Resolution[n] = 100 * \left(1 - \frac{R_{dig}[n]}{R_{dig}[n+1]}\right)$$

$$Setting\_Resolution[n] = 100 * \left(1 - \frac{n}{n+1}\right) = \frac{100}{n+1}$$

As shown above the setting resolution is a function of the resistor value setting.

The setting resolution of the low resistor value as well as of the high value setting is shown below:

$$Setting\_Resolution[1] = \frac{100}{2} = 50\%$$

$$Setting\_Resolution[255] = \frac{100}{256} = 0.4\%$$

## 3  Setting Resolution Requirement for Practical Transmit Power Adjustments

This section examines the setting resolution requirements of a typical optical transmitter.

### 3.1  Definitions and Assumptions

For further examples the following assumptions have been made.

**Table 1. Transmitter Specification**

| Transmitter Specification for OC48 IR-1 1310nm | | | |
|---|---|---|---|
| | min | typ | max |
| Average Power [dBm] | -10 | -6 | -3 |
| Extinction Ratio [dB] | 8.2 | 10 | |

**Table 2. DFB Laser Diode Specification**

| DFB Laser Diode Specification @25C | | |
|---|---|---|
| | mean | sigma |
| Threshold Current [mA] | 10.3 | 0.5 |
| Slope Efficiency [W/A] | 0.102 | 0.008 |
| Monitor Current [mA] | 0.59 | 0.07 |

## 3.2 Setting Resolution Requirement

The setting resolution requirement is vendor specific. For example, 0.1dB for optical average power setting will correspond to a setting resolution of about 2.3% as shown below.

$$Setting\_Resolution = 100 * \left[ 10^{\left(\frac{0.1}{10}\right)} - 1 \right] = 2.3\%$$

already shown the resolution of the resistor value setting can vary between 0.4% and 50%. Using the formula for setting resolution, the range of the digital potentiometer meeting the above stated setting resolution requirement can be determined.

$$Setting\_Resolution[n] = \frac{100}{n+1} = 2.3\%$$

$$n = \frac{100\%}{2.3\%} - 1 \cong 43$$

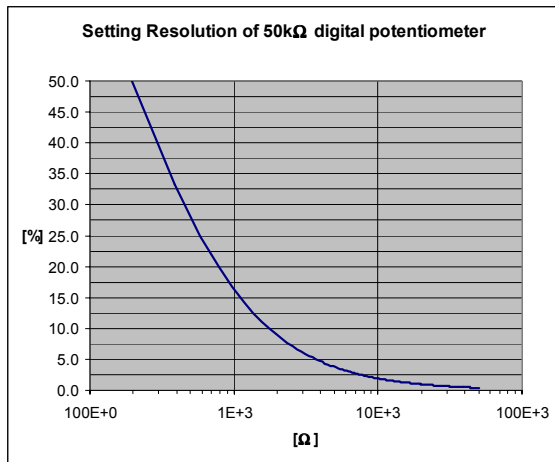$$R_{dig}[43] = 50k\Omega * \frac{43}{256} \cong 8.4k\Omega$$



Figure 1.  *Setting resolution of 50kΩ digital potentiometer*

The calculation and Figure 1 demonstrate that the digital potentiometer provides a resolution of better than 2.3% in a range between 50kΩ and 8.4kΩ.

In many practical cases the resistor value is below 8.4kΩ, leading to significant yield losses in the production. This can be attributed to insufficient resolution in the low end of the digital resistor's setting range.

## 1.3 Practical Adjustment Range for Average Optical Power, and the Extinction Ratio

To determine the necessary adjustment range of the digital potentiometer, the statistical data regarding the part-to-part variation of the used laser diode must be known.

The MAX3735 2.7Gbps SFP laser driver features an input APCSET to control the optical average power, and an input MODSET to control the peak-to-peak optical power.

### 1.1.1 Adjustment Range for APCSET input

$$Adj\_Range = 100 * \left( \frac{Mon\_Current\_Mean + 6\sigma}{Mon\_Current\_Mean} - 1 \right)$$

$$Adj\_Range = 100 * \left( \frac{0.59 + (6*0.07)}{0.59} - 1 \right) = 71\%$$

### 1.1.2 Adjustment Range for MODSET input

$$Adj\_Range = 100 * \left( \frac{Slope\_Eff.\_Mean + 6\sigma}{Slope\_Eff.\_Mean} - 1 \right)$$

$$Adj\_Range = 100 * \left( \frac{0.102 + (6*0.008)}{0.102} - 1 \right) = 47\%$$

## 4 Optimization of the Current Setting Resolution below 8.4kΩ

As seen in Figure 2, combining the digital potentiometer $R_{dig}$ with a parallel fixed resistor $R_p$ will help to reduce the step size, and thus the setting resolution below 8.4kΩ. At the same time the adjustment range will be reduced. To achieve the requested setting resolution and the targeted absolute value of the resistance, an additional fixed resistor $R_s$ must be connected in series with the parallel combination of the digital potentiometer $R_{dig}$ and the fixed parallel resistor $R_p$. A combination of $R_p$ and $R_s$ can be found which satisfies the desired setting resolution and adjustment range.
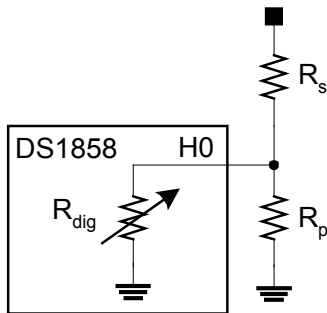


*Figure 2.   Resistors improve setting resolution*

## 5 Calculation of the Setting Resolution and Adjustment Range for Different Values of $R_p$ and $R_s$

An Excel spreadsheet is available that will calculate the optimal values of $R_p$ and $R_s$ for a given setting resolution requirement according to the schematic in Figure 2.

The example in Table 3 uses $R_p$ of 10kΩ and $R_s$ of 1kΩ. For a setting resolution of 2.3% (~0.1dB) the resistor circuitry ranges from 9.3kΩ down to 3.9kΩ providing a dynamic range of about 135%.

For custom settings, please use the following link to download a compressed version of the spreadsheet. The first three parameters in the 'Input Settings' section of the spreadsheet are specific to the DS1858 device. This spreadsheet runs using Microsoft Excel97 (or later versions). If this application is available on your system, you can download the spreadsheet (in compressed form) by going to the following web link:

http://pdfserv.maxim-ic.com/arpdf/AppAttachments/8hfan233.zip

**Table 3. Example of spreadsheet results**

## Input Settings

| | | |
|---|---|---|
| n_max= | 255 | maximum number of discrete positions |
| Rdig[n_max]= | 50E+3 $\Omega$ | typical maximum value of the digital potentiometer |
| Rdig[0]= | 1E+3 $\Omega$ | typical minimum value of the digital potentiometer |
| Setting_Resolution= | 2.3 % | this value limits the usable range of the digital potentiometer |
| Rp= | 10E+3 $\Omega$ | value of the fixed parallel resistor (E24 series) |
| Rs= | 1E+3 $\Omega$ | value of the fixed series resistor (E24 series) |

## Results

| | | |
|---|---|---|
| R[n_max]= | 9.33E+3 $\Omega$ | maximum value of the combined resistance |
| R[0]= | 1.91E+3 $\Omega$ | minimum value of the combined resistance |
| Setting_Resolution[256]= | 0.06 % | setting resolution (SR) at maximum resistance value |
| Setting_Resolution[1]= | 7.56 % | SR at minimum resistance value |
| R[n]= | 3.97E+3 $\Omega$ | resistance value at which the req. SR has been exceeded |
| n= | 17 | position of the digital potentiometer at which the req. SR has been exceeded |
| dynamic_range= | 135 % | percentage of the relation R[255]/R[n] showing the range meeting the SR req. |