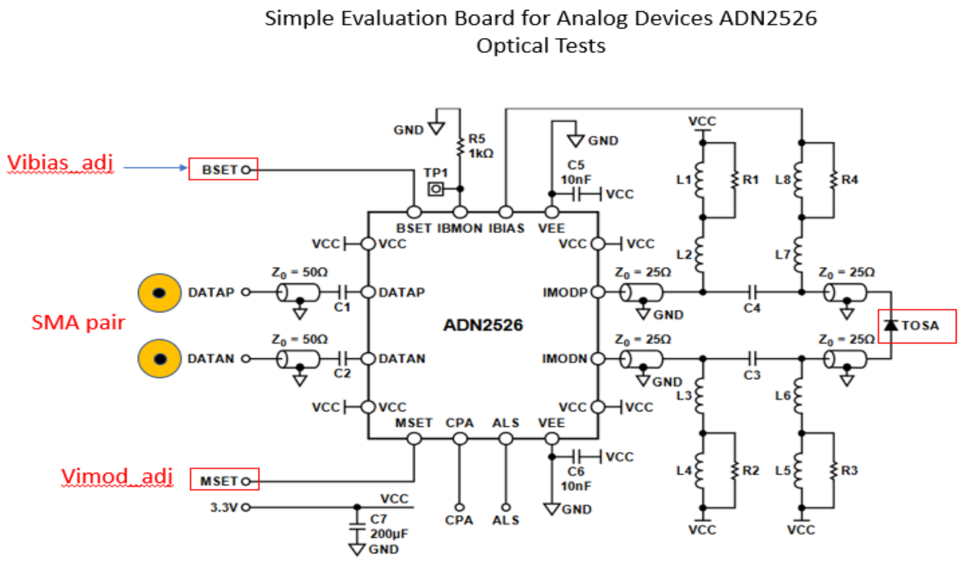
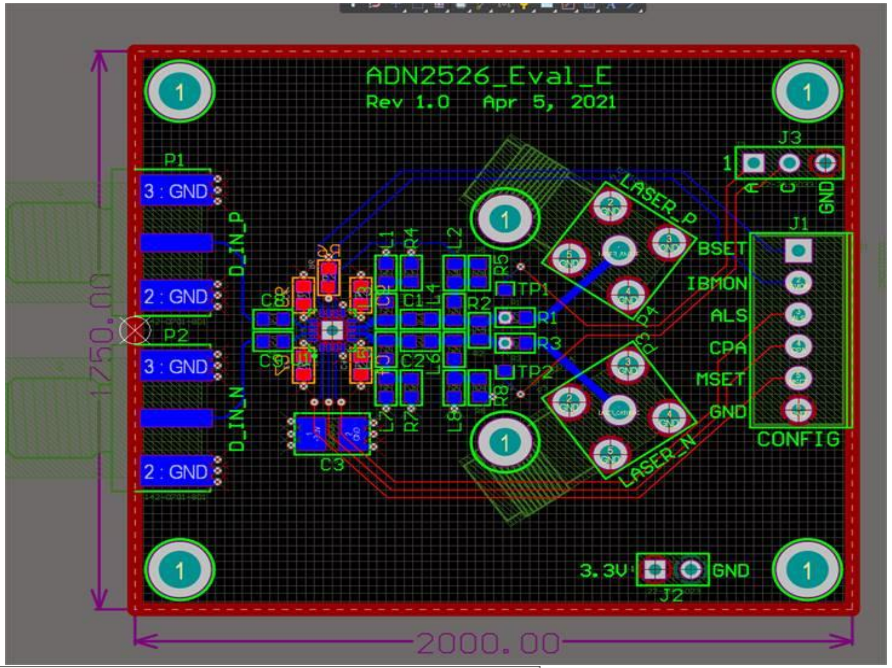
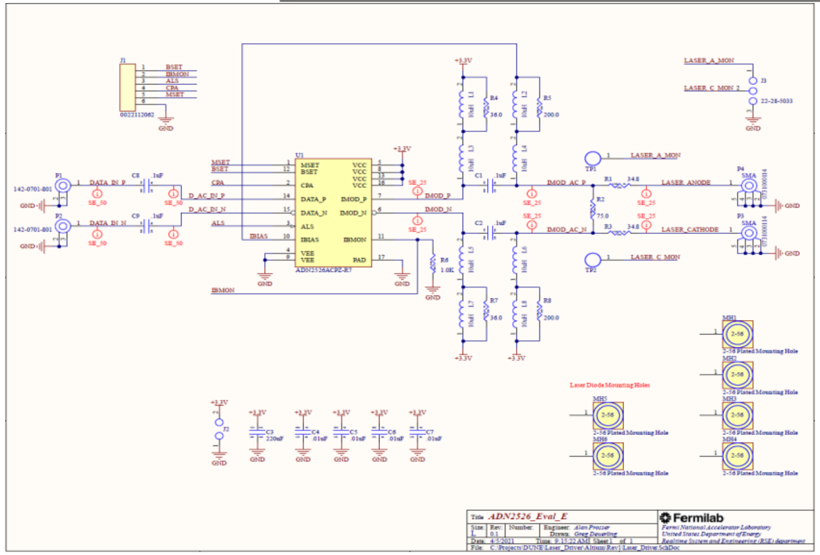
DUNE Cryogenic Optical Links
VD/PhD Meeting Update

April 14, 2021

Testing with ADN2526 Custom LN2 Board







Room temperature testing first,
followed by testing in LN2

- Electrical Testing
- Optical Testing with Pigtailed FP Laser from Newport (lased in LN2).

Component Procurement for Testing

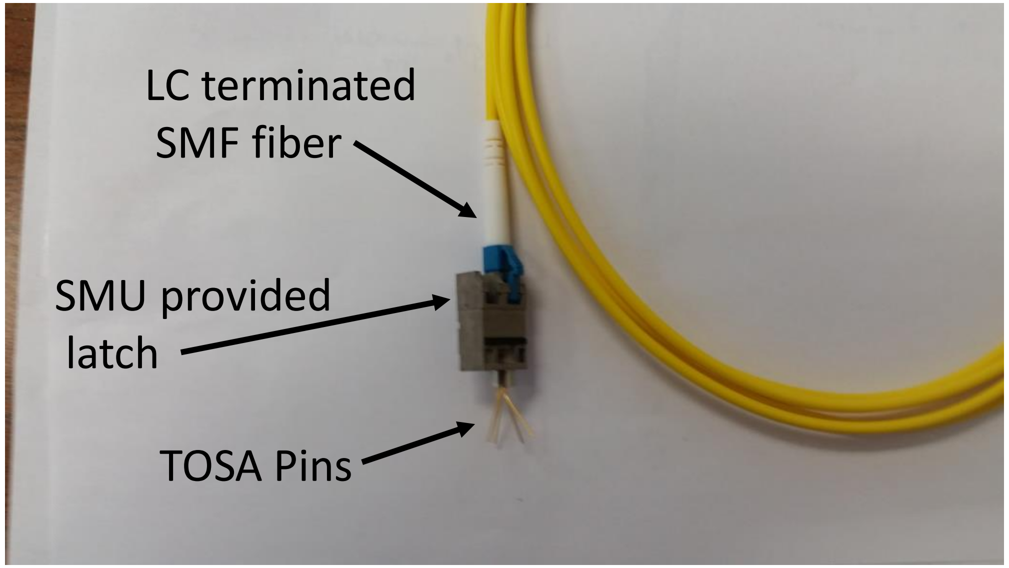
We are about to place an order for FP and DFB laser diodes from Vitex (pigtailed).

We are in discussions with Truelight (Taiwan) thanks to help from Jingbo Ye (SMU) and Suen Hou (Academia Sinica). The information exchange with Truelight has been ***outstanding*** (timely, thorough). Partners like this make all the difference.

Truelight components are priced much more attractively than comparable components found on distributor websites.

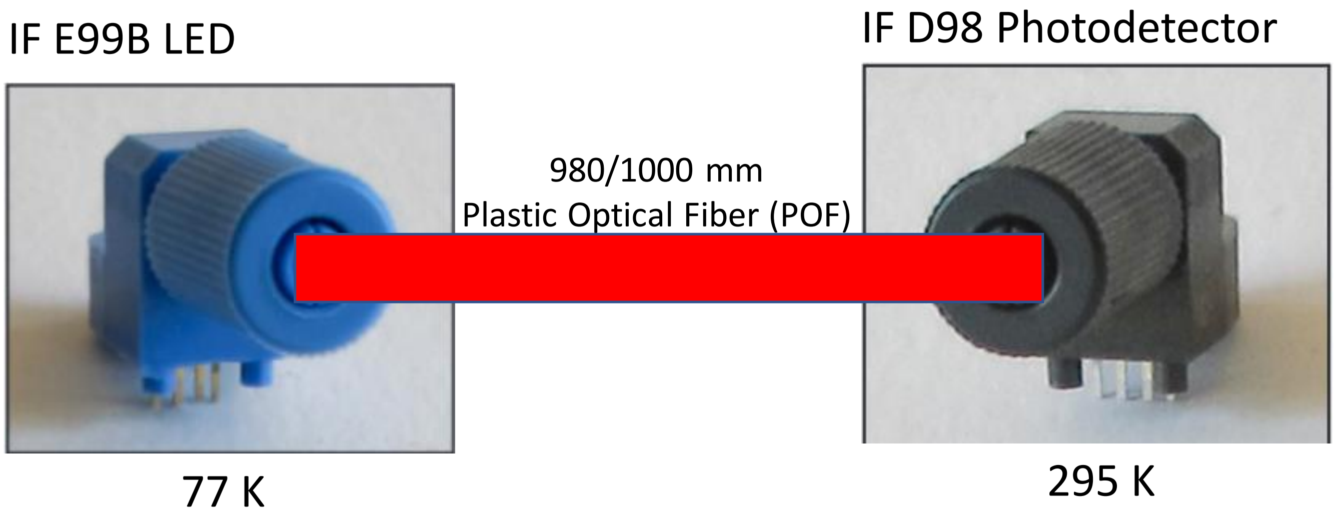
Unfortunately, the Truelight FPs and DFBs are not available in pigtailed format.

The arrangement on the right can be attempted using latches from Andy Liu (SMU). However, those latches appear to no longer be available (we have 8).



We are in discussions with CERN (Jan Troska) to obtain some of their (exclusive) VTRx LC latches. Potential issue around the variation of mechanical dimensions of EEL TOSAs.

156 Mbps Link over POF



For use in either uplink or downlink, one device will be warm, one device will be cold.

We have seen shifts in the spectrum on the order of 80-90 nm from 295 K to 77 K.

Can we predict the shift for these devices (different material system from 1310 nm laser diodes we have measured)?

Can we estimate the expected performance impact due to the shift?

IF E99B 156 Mbps Fiber Optic Red LED

Room temperature relative intensity

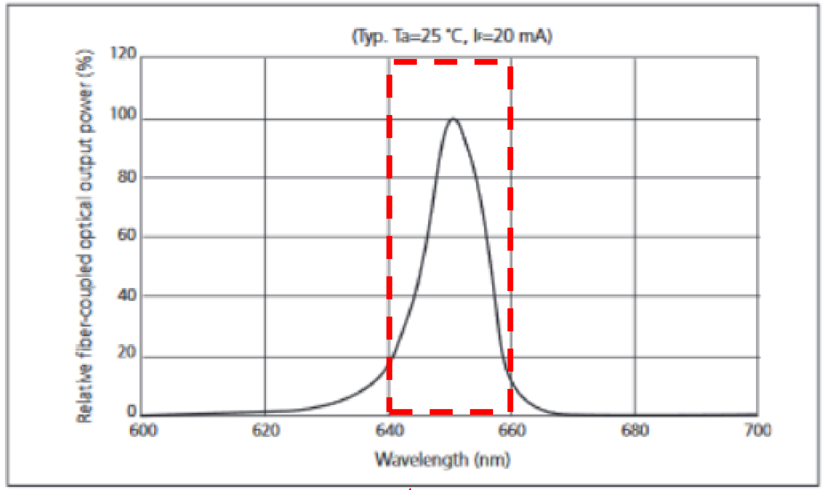


FIGURE 1. Relative intensity versus wavelength.

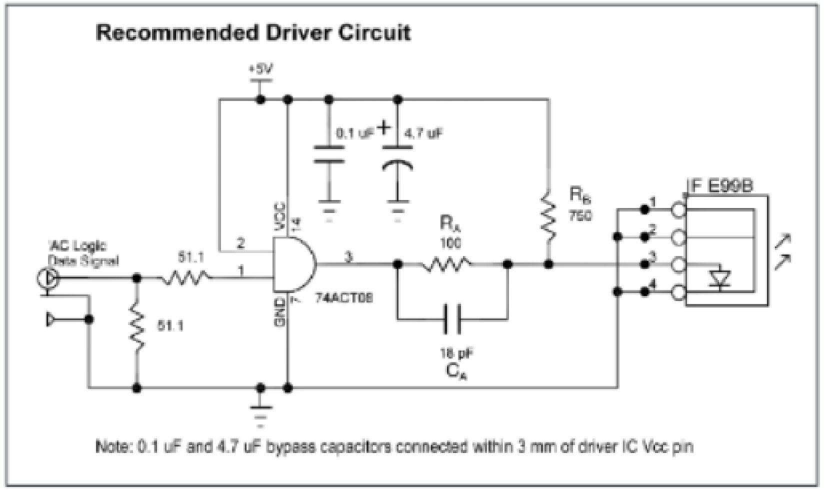
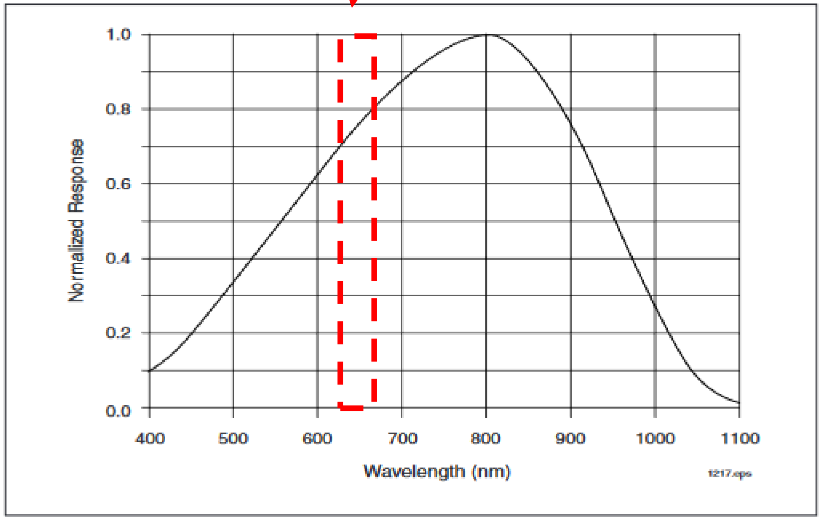


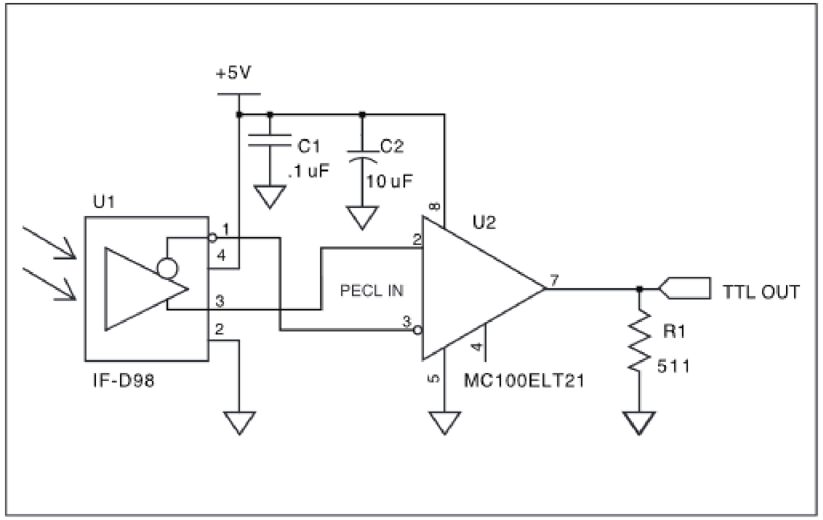
FIGURE 3. Typical interface circuit. (IF = 35mA).

If driven by 3.3V FPGA bank, a level translator will be needed.

IF D98 Fiber Optic 155 Mbps Photologic Detector

Responsivity of the recommended complementary photodiode





If driving a 3.3V FPGA bank, a level translator will be needed.

GaAs Spectral Shift Estimate (850 nm SFP+)

The temperature dependence of the energy bandgap has been experimentally determined yielding the following expression for E_g as a function of the temperature T:

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{T + \beta}$$

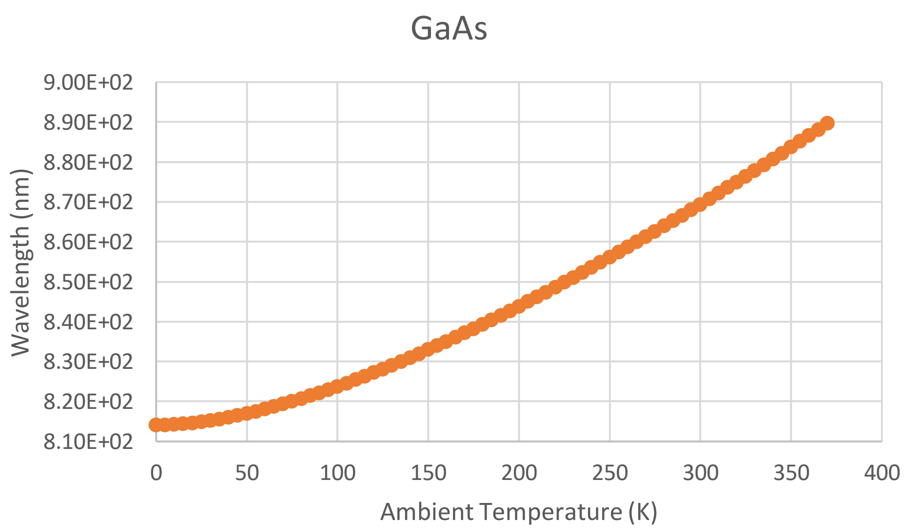
*Varshni's Equation (From Refs 1,2)**

where $E_g(0)$, a and b are the fitting parameters. These fitting parameters are listed for germanium, silicon and gallium arsenide in the table below:

	Germanium	Silicon	GaAs
$E_g(0)$ [eV]	0.7437	1.166	1.519
a [eV/K]	4.77 x 10^{-4}	4.73 x 10^{-4}	5.41 x 10^{-4}
b [K]	235	636	204

Value of *h*	Units	Ref.
6.626 070 15 × 10^{-34}	J⋅s	[1][note 1]
4.135 667 696 × 10^{-15}	eV⋅s	[note 2]

$$\lambda = \frac{hc}{E_g(0) - \frac{\alpha T^2}{T + \beta}}$$



What about $Al_xGa_{1-x}As$ (for 650 nm LED)?

λ = 868 nm @ 295 K

λ = 820 nm @ 75 K

*Ref 1: https://ecee.colorado.edu/~bart/book/eband5.htm
Ref 2: Physica, Volume 34, Issue 1, 1967, Pages 149-154

$Al_xGa_{1-x}As$ Spectral Shift Estimate (Red LED)

Assume λ = 650 nm (spectral peak from LED data sheet).

Compute the room temperature band gap, $E_\Gamma(295\ K) = \dfrac{hc}{\lambda} = 1.9$ eV

Using $E_\Gamma(295\ K)$ = 1.9 eV, solve the following for x:

Energy gap x<0.45 1.424+1.247x eV = $E_\Gamma(295\ K)$ *(From Ref 3*)*

Answer: x = 0.38

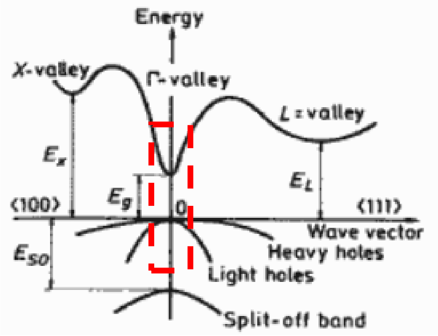
Next, solve for $E_\Gamma(T)$ using:

$$E_\Gamma = E_\Gamma(0) - \underset{\alpha}{5.41\cdot10^{-4}}\cdot T^2/(T+\underset{\beta}{204})\ (\text{eV})$$

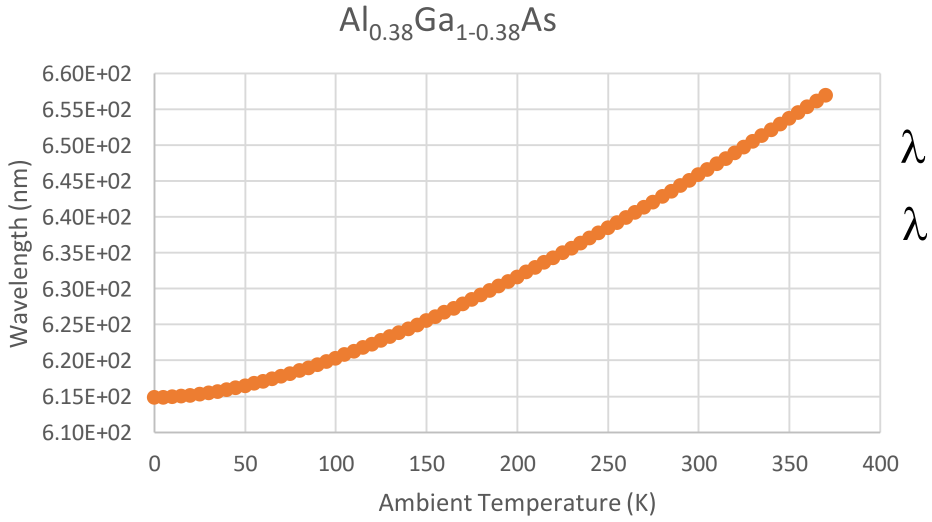
$$\text{where } E_\Gamma(0) = 1.519 + 1.155x + 0.37x^2\ (\text{eV})$$

$E_\Gamma(0\ K)$ = 2.01 eV

$$\lambda = \frac{hc}{E_\Gamma(0\ K) - \dfrac{\alpha T^2}{T+\beta}}$$



$Al_xGa_{1-x}As$ Band Structure



λ = 645 nm @ 295 K

λ = 618 nm @ 75 K

**Ref 3: http://www.ioffe.ru/SVA/NSM/Semicond/AlGaAs/bandstr.html#Temperature*

λ = 645 nm @ 295 K

λ = 618 nm @ 75 K

IF D98 Fiber Optic 155 Mbps Photologic Detector

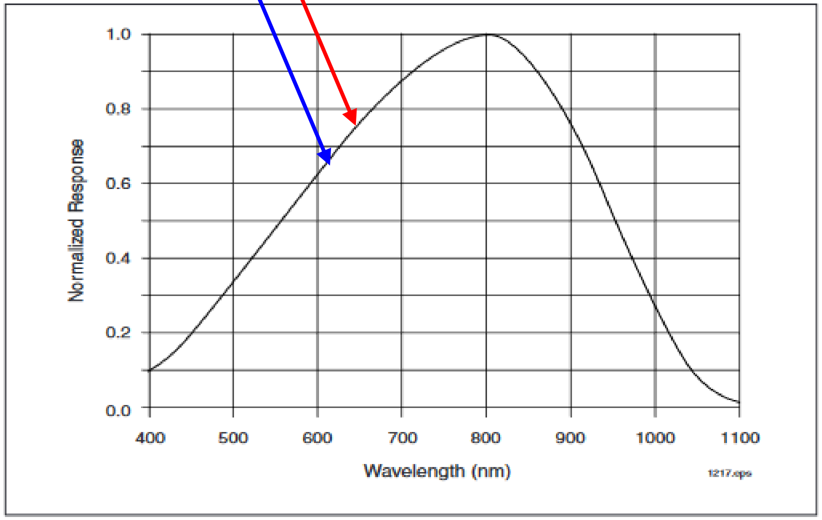


FIGURE 1. Normalized detector response versus wavelength.

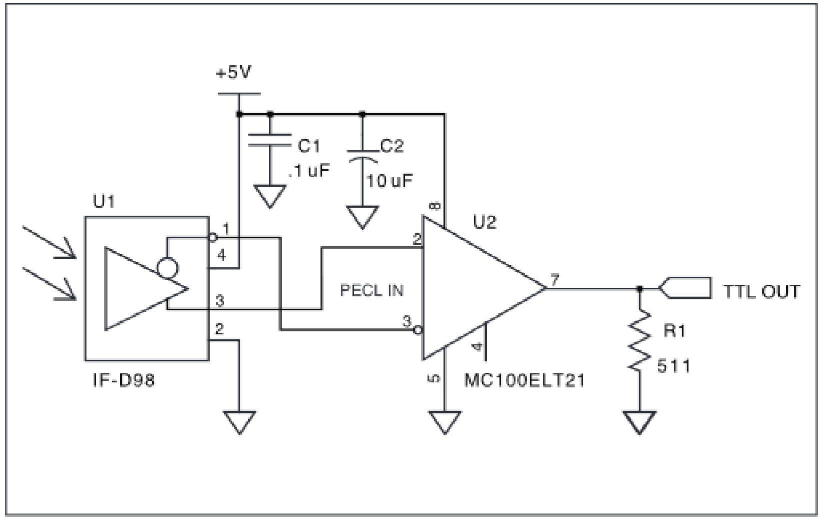


FIGURE 2. Typical interface circuit.

Conclusion:
Change in the normalized response estimated to be ~10%. We will purchase several of each of the devices in this complementary pair (LED, photodetector) as well as the necessary interface components and design test hardware for evaluation (@ 295 K and 77 K respectively)