Optoelectronics

Application Note

Driving an Infrared Emitter in Steady and Pulsed Operating Modes




Vishay's infrared emitters are offered in a wide spectrum of packages, peak wavelengths, radiant intensities, and angles of half intensity. These emitters are defined for steady (continuous) and pulsed operating modes.

The absolute maximum rating normally shown for the allowed continuous forward current is I_F = 100 mA. Pulsed operating mode is often only indicated by the values "Peak forward current" and "Surge forward current." For "Peak forward current," the pulse/pause ratio is given as t_p/T = 0.5, and the pulse length is defined as t_p = 100 µs.

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	5	V
Forward current		I_F	100	mA
Peak forward current	t_p/T = 0.5, t_p = 100 µs	I_{FM}	200	mA
Surge forward current	t_p = 100 µs	I_{FSM}	1.5	A
Power dissipation		P_V	160	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	- 40 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	t ≤ 5 s, 2 mm from case	T_{sd}	260	°C
Thermal resistance junction/ambient	J-STD-051, leads 7 mm, soldered on PCB	R_{thJA}	250	K/W

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Within many datasheets, the following diagram is available to show the possible forward current when operating the IRED with shorter pulses and/or longer repetition times.

As shown, for pulses $t_p \leq 100$ µs, only the repetition time limits the possible maximum forward current.

For pulses $t_p \geq 100$ µs, heating up of the component could occur, so the forward current needs to be decreased compared with possible maximum current for pulses ≤ 100 µs.

The example below shows the possible current when operating the device with a pulse length of $t_p = 2$ ms.

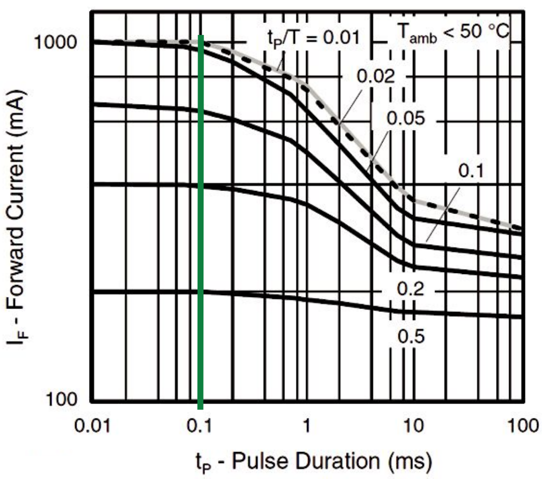

Fig. 1 - Pulse Forward Current vs. Pulse Duration

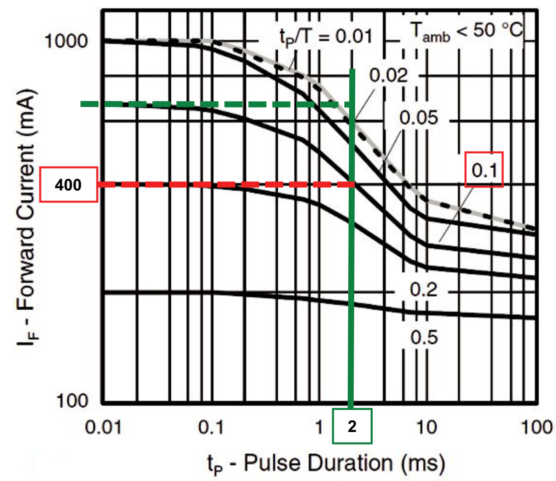

Fig. 2 - Pulse Forward Current vs. Pulse Duration

As shown in the example, with $t_p = 2$ ms and $t_p/T = 0.1$, a maximum current of 400 mA is possible, instead of more than 600 mA if the pulses were shorter than 100 µs.

$t_p/T = 0.1$ means that with a given pulse length of 2 ms, the total period is: $T = t_p/0.1 = 2$ ms x 10 = 20 ms.

So there is time enough with that 18 ms of pulse pause to cool down again.

In addition, the calculated average current is low enough: $I_{ava} = I_{max.}/(T/t_p)$ = 400 mA/(20 ms/2 ms) = 400 mA/10.

What also needs to be considered for correct current calculation is the possible ambient temperature at which the device is operating. In the above figures it is already mentioned that this is only valid for temperatures below 50 °C.

For most infrared emitters, the total power dissipation is limited to $P_V = 160$ mW, or $P_V = 180$ mW.

New surface emitter technology allows up to 200 mW (depending on the package). The maximum ambient temperature is defined for 85 °C, and maximum junction temperature is $T_j = 100$ °C.

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	**TEST CONDITION**	**SYMBOL**	**VALUE**	**UNIT**
Reverse voltage		V_R	5	V
Forward current		I_F	100	mA
Peak forward current	$t_p/T = 0.5$, $t_p = 100$ µs	I_{FM}	200	mA
Surge forward current	$t_p = 100$ µs	I_{FSM}	1	A
Power dissipation		P_V	180	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	- 40 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	t ≤ 5 s, 2 mm from case	T_{sd}	260	°C
Thermal resistance junction/ambient	J-STD-051, leads 7 mm, soldered on PCB	R_{thJA}	230	K/W

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The first two limits (P_V and T_{amb}) are evaluated by the characteristic curve of the chip. The bevel is calculated unsing R_{thJA}, which provides the gradient of the bevel.

The figure below is taken from devices specified with 180 mW as the max. P_V and a R_{thJA} of 230 K/W. These specifications can be found in the TSHG family, e.g.: TSHG8200 or TSHG6210.

Either P_V or just the applied forward current I_F lead to the derating diagrams.

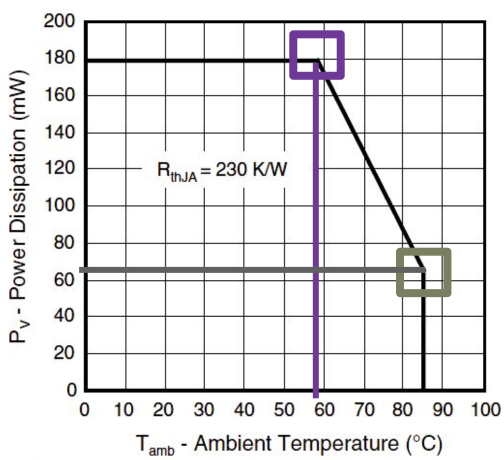


Fig. 3 - Power Dissipation Limit vs. Ambient Temperature

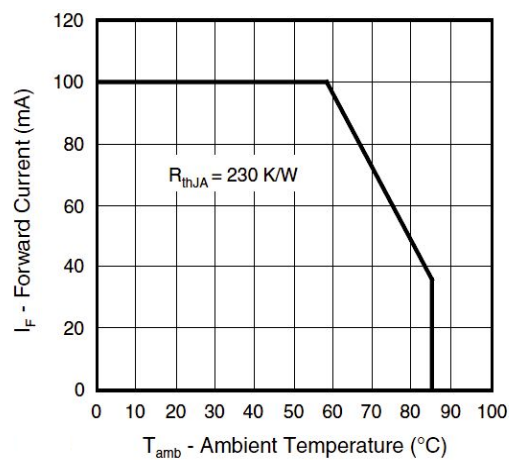


Fig. 4 - Forward Current Limit vs. Ambient Temperature

The formula used (for violet marked) is:

$100\ °C = T_{amb} + R_{thJA} \times P_V$
(with $P_V = 0.18$ W, $R_{thJA} = 230$ K/W)
($T_{amb} = T_j - R_{thJA} \times P_V = 100\ °C - 230\ K/W \times 0.18\ W = 100\ °C - 41.4\ K = 58.6\ °C) \rightarrow T_{amb} = 58.6\ °C$

The formula used (for grey marked) is:

$100\ °C = 85\ °C + R_{thJA} \times P_V \rightarrow P_V = 65.2$ mW

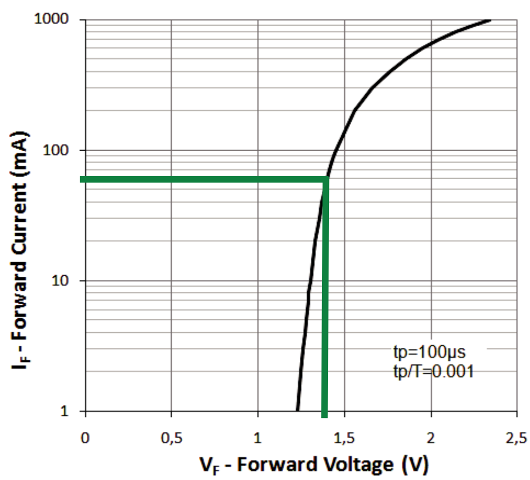
Driving an Infrared Emitter in Steady and Pulsed Operating Modes

CHOOSING A SERIES RESISTOR

Each datasheet includes a forward current vs. forward voltage graph which can be used to determine the value of the series resistor.

The example below is measured from a VSMG3700.

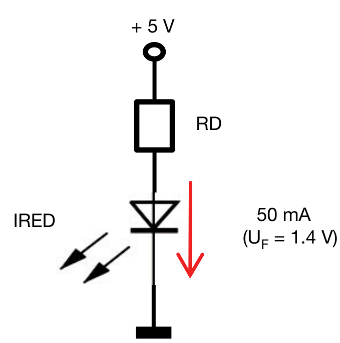
At 100 mA, the typical forward voltage is shown as 1.5 V, and 2.3 V at 1 A. The curve for the different currents is also available within the datasheets.



Driving this diode with a constant current of 50 mA would give a typical forward voltage of 1.4 V.

With a supply voltage of 5 V, the series resistor is then calculated for 73 Ω. Next value within the E24 table would be 75 Ω.

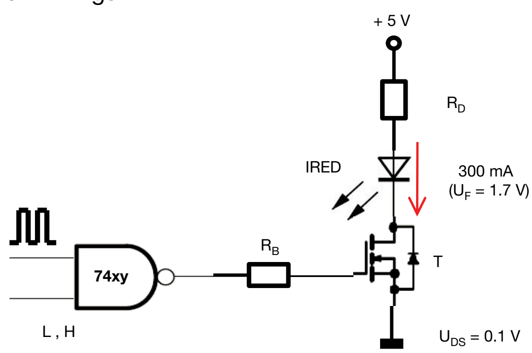
R_D = (5 V - 1.4 V)/0.05 A = 73 Ω → 75 Ω



Driving an Infrared Emitter in Steady and Pulsed Operating Modes

Pulsing the IRED is often realized by adding a fast FET in line with the emitter. The wanted/needed pulse signal is delivered directly by an application controller or a dedicated generator.

For more than one emitter, these IREDs may be put together, all driven by the same source and the switching transistor. Often a FET is used here, offering faster on/off timings.

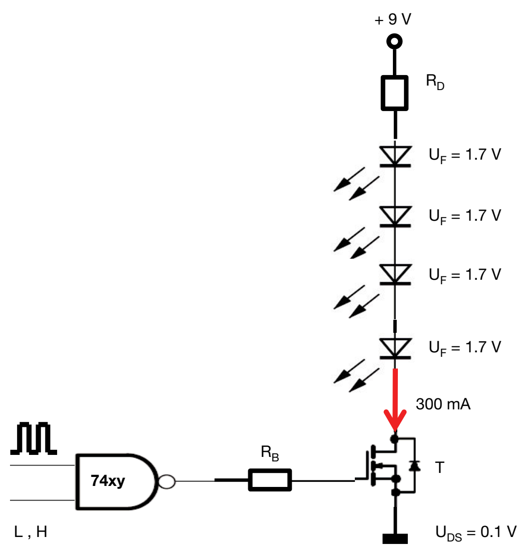


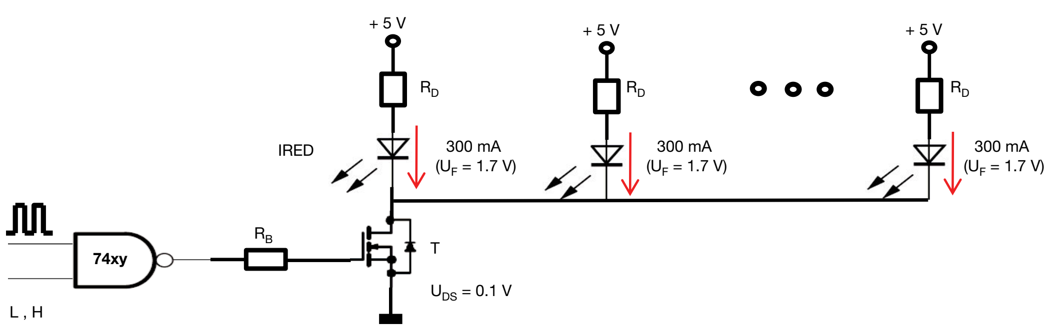
Simple drive stage with one IRED.

R_D = (5 V - 1.7 V)/0.3 A = 10.7 Ω ⟶ 12 Ω

Also, the connection of few emitters in series is a possibility. This would then require a higher supply voltage.

The calculation for the current limiting resistor is similar to before, but now with 4 x U_F:
R_D = (9 V - 4 x 1.7 V - 0.1 V)/0.3 A = 7 Ω → 7.5 Ω





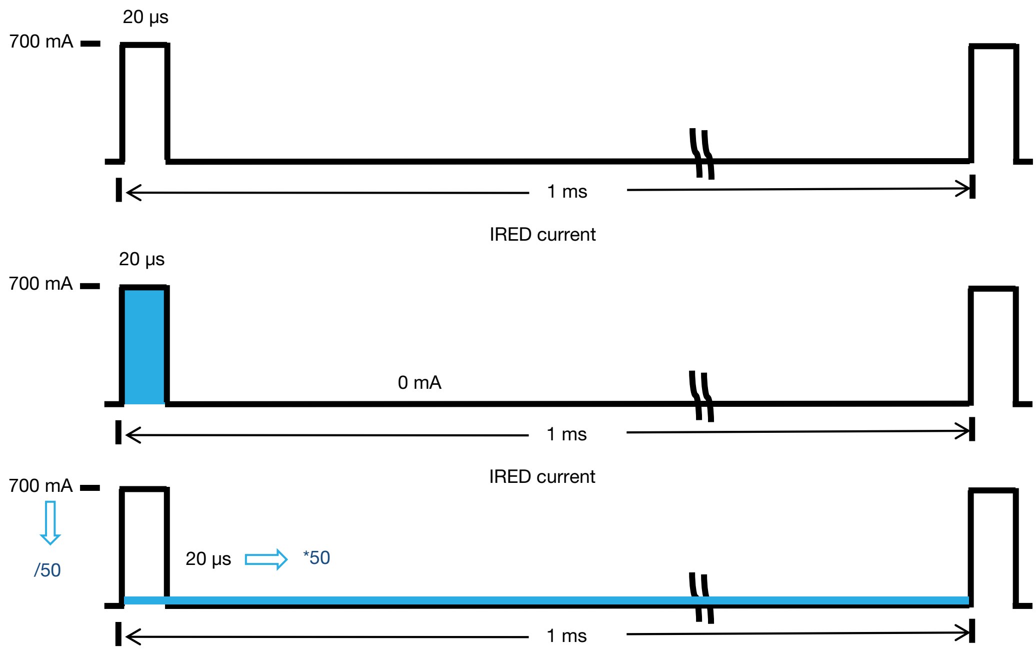
Parallel connection of the IREDs would require a dedicated current limiting resistor for each, as all dedicated components will come with different forward voltages and a parallel connection could destroy the IREDs.

Driving an Infrared Emitter in Steady and Pulsed Operating Modes

Driving the IREDs with high current, but with short pulses and long repetition times, often will not cause thermal stress, as this operating mode is usually uncritical in terms of total power dissipation.

For the example below, a current of 700 mA is chosen. This is possible with most of our IREDs with a given pulse pattern of tp = 20 µs and a period of 1 ms.

The calculated tp/T will just be 20 µs/1000 µs = 2/100 = 0.02



Example calculation:
Chosen IRED TSHG5410 or TSHG6410 with typical V_F = 2.1 V for I_F = 700 mA.

The average current will be just:
I_{ava} = 700 mA/(1000 µs/20 µs) = 700 mA/50 = 14 mA.

And the average power dissipation just P_{vava} = 700 mA x 2.1 V/50= 1470 mW/50 = 29.4 mW

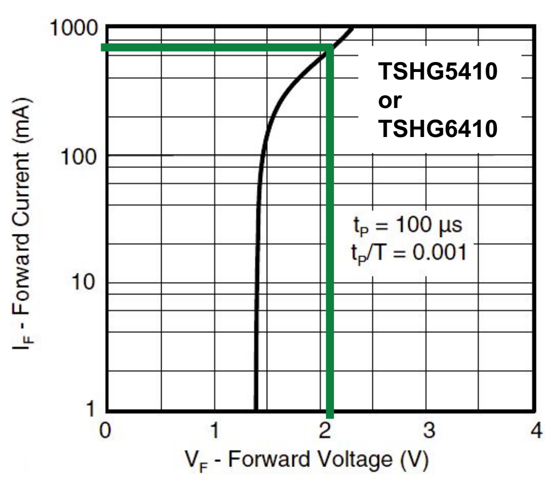


Fig. 5 - Forward Current vs. Forward Voltage

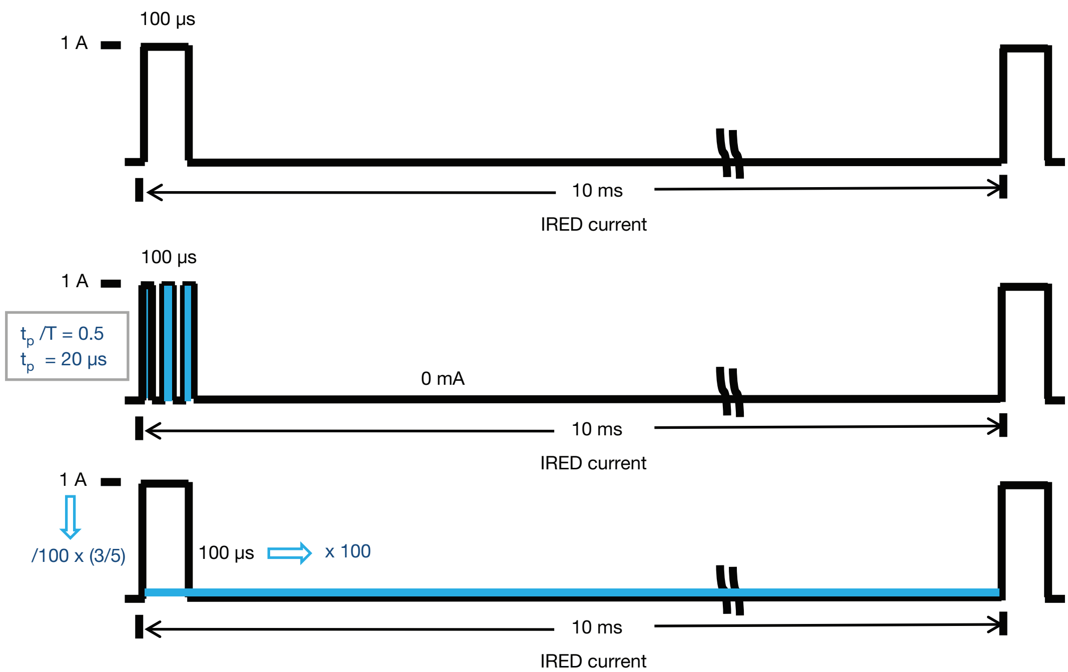
Driving an Infrared Emitter in Steady and Pulsed Operating Modes

Often the pulse pattern is even more uncritical, such as when emitters are used within 3D-TV applications.

Here, the repetition time is related to the vertical synchronization, e.g. for 100 Hz 1/100 Hz = 10 ms.

The calculated t_p/T is then 100 µs/10 000 µs = 1/100 = 0.01.

This 100 µs is often a kind of burst that decreases the average power even further.



Example calculation:

t_p = 0.1 ms → 100 µs; I_F = 1000 mA → t_p/T = 0.01 → T = t_p/0.01 = 100 µs/0.01 = 10 000 µs = 10 ms

The average current is then:

I_{ava} = 1 A/(10 000 µs/60 µs) = 1 A/167.33 = 6 mA

Driving an Infrared Emitter in Steady and Pulsed Operating Modes

As shown in the previous examples, just calculating the average DC current when driving the IRED with pulses does not lead to the specified maximum allowed current.

As demonstrated in the example on page 2, with a pulse of t_p = 2 ms and a repetition time of 20 ms (t_p/T = 0.1), a maximum current of 400 mA is possible. This leads to an average current of 40 mA.

Within this diagram, it is noted that this average current is also only possible up to T_{amb} < 50 °C.

The maximum DC current that is normally specified with 100 mA is only possible with the given “room” temperature of 25 °C.

Whenever the operating temperature could be higher, one has to calculate the current decrease accordingly.

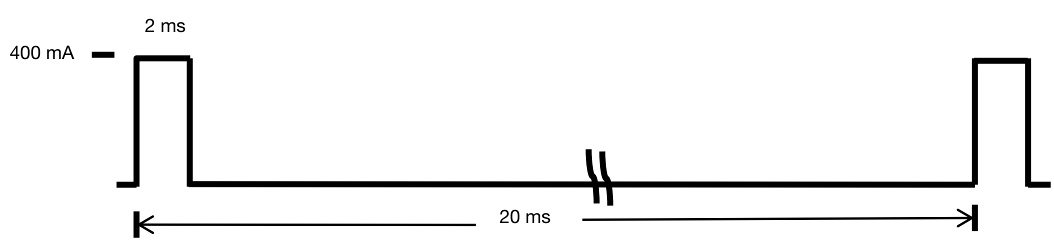
The junction temperature must never exceed the maximum defined 100 °C.

How can this be measured?

The simplest method would be to just monitor the forward voltage.

Within the datasheets of the IREDs, the temperature coefficient of the V_F is always given, and ranges from - 1 mV/K to - 2 mV/K. If one measures the forward voltage at the start of operation at the maximum defined operating temperature (e.g. 60 °C), [V_{F1}] and then again after about 3 min to 5 min [V_{F2}], it will show a lower value than before.

The difference will give the increase of the junction temperature by calculating using the temperature coefficient.



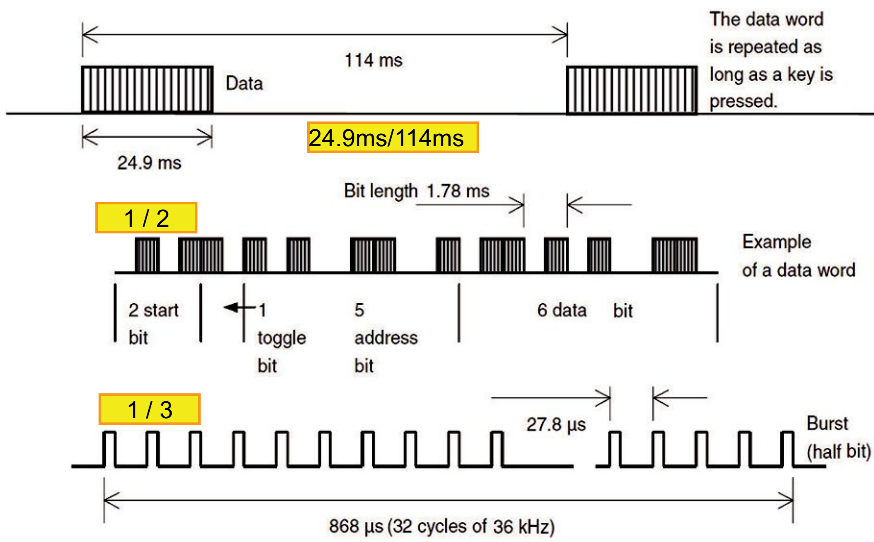
1. Measure V_{F1} at the first pulse, e.g. 1.8 V (approx V_F at 400 mA)
2. Allow the IRED to heat up for about 3 min to 5 min
3. Measure V_{F2} at the end of the last pulse, e.g. 1.72 V
4. Calculate delta V_F, e.g. for the above: $V_{F2} - V_{F1}$ = 1.72 V -1.8 V = - 80 mV
5. Calculate the temperature difference with the formular: $\Delta T = \Delta V_F/TK_{VF}$ = - 80 mV/- 1.8 mV/K = 44.4 K (here TK_{VF} is found within the datasheet: - 1.8 mV/K)
6. Add this delta temperature to the defined max. ambient temperature: $T_{junc} = T_{amb\ max.} + \Delta T$ = 60 °C + 44.4 °C

With 104.4 °C, the max. allowed junction temperature is exceeded.

So, either the defined operating temperature can be max. 55.6 °C, or the drive conditions need to be adapted with lower current, shorter pulse times, and/or longer repetition time.

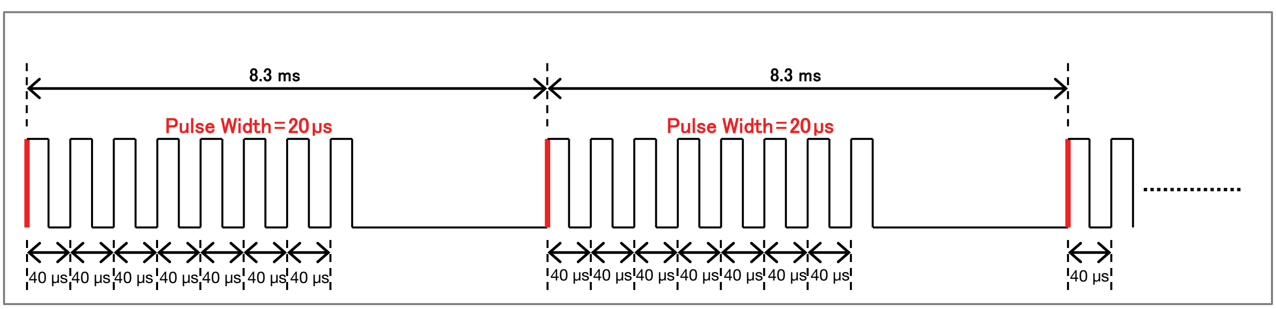
Driving an Infrared Emitter in Steady and Pulsed Operating Modes

EXAMPLES OF PULSE DIAGRAMS AND POSSIBLE PULSED EMITTER CURRENT



Example of a familiar IR protocol: RC5

The calculated t_p/T for this pulse pattern is: 24.9 ms/114 ms x 1/2 x 1/3 $\rightarrow$ t_p/T = 0.04



Example of a pulse burst for synchronizing 3D glasses

The calculated t_p/T for this pulse pattern is: 8 x 40 µs/8.3 ms x 1/2 $\rightarrow$ t_p/T = 0.02

Driving an Infrared Emitter in Steady and Pulsed Operating Modes

EXAMPLES OF NEEDED EMITTER CURRENT FOR A PHOTODETECTOR IN DEFINED DISTANCE

For calculating the needed emitter current, the required irradiance for the detector is needed and the distance between the emitter and detector has to be defined.

If the detector is an IR receiver, one needs just about 0.1 mW/m^2, because these devices are quite sensitive and incorporate a built-in high AGC.

With a photodiode or a phototransistor as the detector, one needs much more irradiance to get enough output current. Fig. 6 below shows that with an Irradiance [E_e] = 10 μW/cm^2 (= 100 mW/m^2), one gets about 4 μA of collector light current.

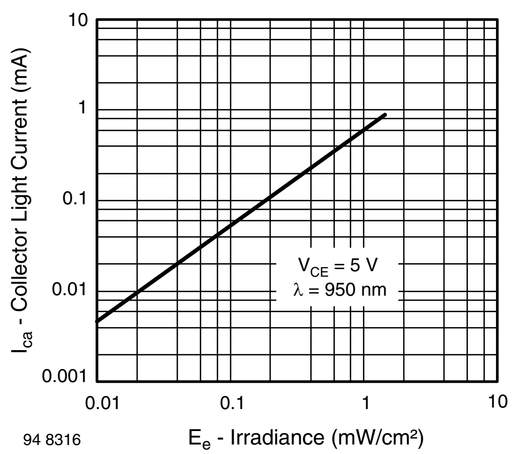


Fig. 6 - Collector Light Current vs. Irradiance

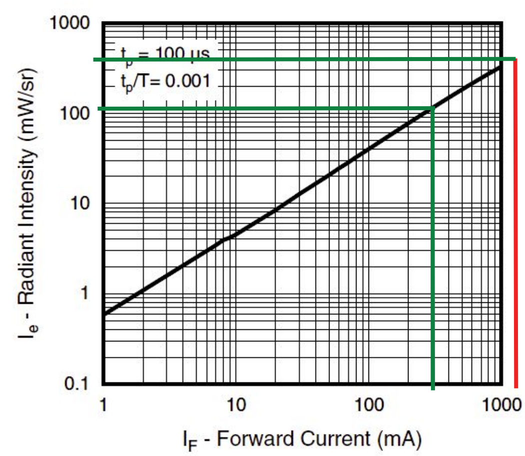


Fig. 7 - Radiant Intensity vs. Forward Current

It has to be noted that the available irradiance reaching the detector is decreasing inverse squared with the distance. Calculating needs to be done according to this "Inverse Square Law": $\mathbf{E_e = I_e/d^2}$.

So the chosen emitter has to have a radiant intensity [I_e] of: $\mathbf{I_e = E_e \times d^2}$.

To get an irradiance [E_e] of 10 μW/cm^2 (= 100 mW/m^2) in a distance of 1 m from the emitter, one needs a radiant intensity [I_e] of **100 mW/m^2 x (1 m)^2 = 100 mW/sr**, but for d = 2 m it needs four times the intensity:
I_e = 100 mW/m^2 x (2 m)^2 = 400 mW/sr.

Fig. 7 above shows that this 100 mW/sr is only possible with a forward current of about 300 mA. Allowing this high current requires pulsed mode for the emitter with short pulses and longer repetition times, as discussed in this application note.

For the 400 mW/sr above, the chosen emitter seems to not be powerful enough, so either an even more powerful IRED needs to be selected or two samples need to operate together.