MLX91220 Application Note

Over Current Detection

Contents

1. Scope

The MLX91220 is an Integrated Current Sensor that senses the current flowing through the leadframe of the SOIC package. By virtue of fixing the current conductor position with respect to the monolithic CMOS sensor, a fully integrated Hall-effect current sensor is obtained, that is factory calibrated.

For the SOIC16 package version, the MLX91220 provides two OCD features that allow detecting overcurrent applied on the integrated sensor primary. The detection of overcurrent does not trigger any internal safety mechanism. It is up to the application to use the overcurrent **information**.

The internal overcurrent detection level is factory calibrated and is used for detecting dangerously high current to prevent short circuits for example.

The external overcurrent detection level can be set by the user through external resistance connected to V_{DD} and V_{REF} or through an external reference level.

2. SOIC16 Pinout

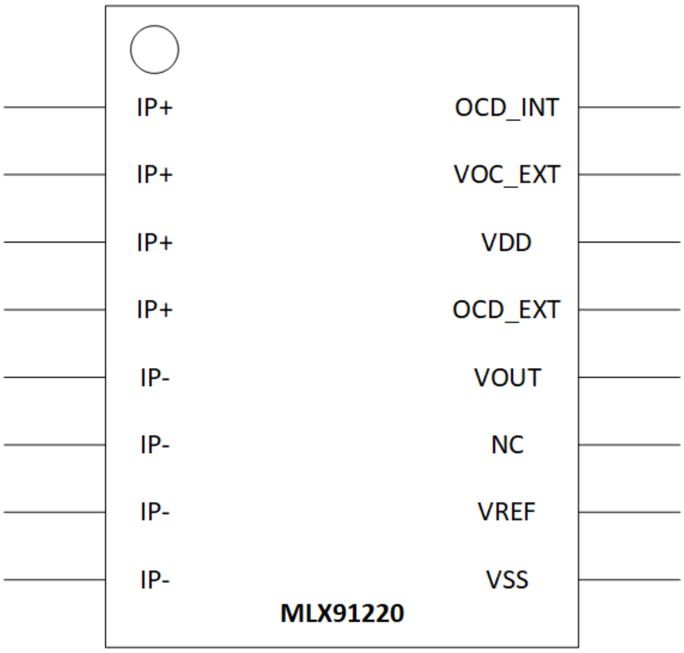


Figure 1 - MLX91220 SOIC16 Pinout

PIN	Pin name	Function
1	IP+	Primary Current Path Input
2		
3		
4		
5	IP-	Primary Current Path Output
6		
7		
8		
9	VSS	Ground Voltage
10	VREF	Reference Voltage
11	*NC*	*Not connected*
12	VOUT	Output Voltage
13	OCDEXT	External Overcurrent detection
14	VDD	Supply Voltage
15	VOCEXT	External Overcurrent threshold voltage
16	OCDINT	Internal Overcurrent Detection

3. General

During normal operation the OCD voltage remains at V_{DD}. This OCD feature is available for SOIC16 version only. In case of OCD detection, the OCD_{INT} or OCD_{EXT} is pulled to ground.

The two OCD functions are able to react to an overcurrent event within few µs of response time. To avoid false alarm, the overcurrent has to be maintained at least 1µs (for OCD_{INT}) or 10µs (for OCD_{EXT}) for the detection to occur. After detection by the sensor the output flag is maintained for 10µs of dwell time. This allows the overcurrent to be easily detected at microcontroller level.

	OCD_INT		OCD_EXT	
	Min	Max	Min	Max
Typical Application	Short-circuit detection		Out-of-range detection	
Overcurrent effect	OCD_{INT} pin to V_{SS}		OCD_{EXT} pin to V_{SS}	
Detection mode	Bidirectional		Unidirectional / bidirectional	
Accuracy	Lower		Higher	
Threshold trimming	EEPROM		Voltage divider on VOC_{EXT}	
Response time	1.4µs	2.1µs	10µs typical	
Required Input holding time	1µs		10 µs minimum	
OCD output dwell time	10µs		10µs	

Table 1 - Comparison between OCD_{INT} and OCD_{EXT} performances

4. Electrical Specifications

DC Operating Parameters at V_{DD} = 3.3V or 5 V (unless otherwise specified) and for T_A as specified by the Temperature suffix (K).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
OCD_INT Internal ON Resistance	$R_{ON\_OCD\_INT}$	I_{SINK} = 1 mA	60	90	150	Ω
OCD_EXT Internal ON Resistance	$R_{ON\_OCD\_EXT}$	I_{SINK} = 1 mA	160	190	280	Ω
VOC_EXT Voltage Range	VOC_EXT	MLX91221, V_{DD} = 3.3 V	0.3		1.2	V
		MLX91220, V_{DD} = 5 V	0.3		2	V
OCD_{EXT} threshold error	ε_{EOCD}		-6		6	%
OCD_{INT} Accuracy Error! Reference source not found.	ε_{IOCD}	Cf. Table 3 - OCD_{INT} threshold currents and accuracy limits for SOIC-16 versions				

5. Internal Overcurrent Detection principle

The internal OCD takes fixed threshold voltage values predefined in the EEPROM and do not require any extra components. The OCD_{INT} implementation allows detecting overcurrent outside of the output measurement range of the sensor and is therefore suitable for large current peaks as occurring during short-circuits. If the theoretical sensor output overcomes the OCD_{INT} voltage threshold, the overcurrent event is flagged on OCDINT pin. The internal OCD offers a faster response than OCD_{EXT} but the threshold is defined less accurately. The default OCD threshold voltages are defined as follow, but other values can be set on request. The overcurrent threshold in ampere is deduced from the sensitivity of the sensor [mV/A] and the OCD_{INT} threshold voltage.

	Sensor configuration	Min.	Max.
OCD_{INT} Threshold [% FS]	V_{DD} = 5V / V_{REF} = 2.5V	27.2	230
	V_{DD} = 5V / V_{REF} = 0.5V	13.6	288
	V_{DD} = 3.3V / V_{REF} = 1.65V	43.6	368.4

Table 2: OCD_{INT} factory programmable range

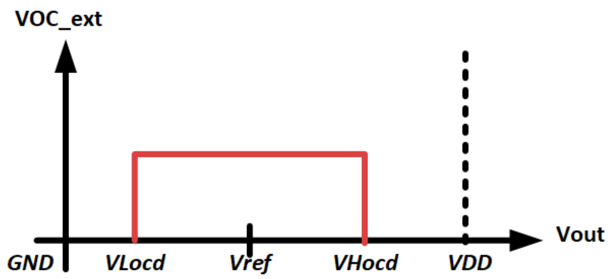
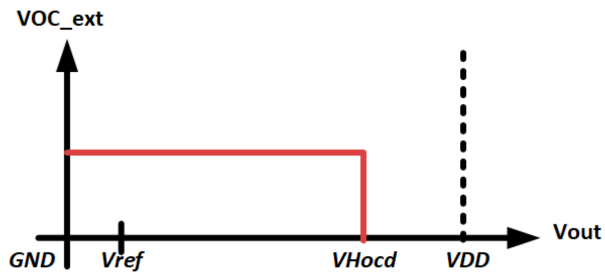
Sensor reference	Sensitivity [mV/A]	OCD_{INT} Threshold Current [% *FS*]	OCD_{INT} Threshold Current	Typical OCD_{INT} Accuracy Ta= 25°C	Typical OCD_{INT} Accuracy Ta= -40°C to 85°C
MLX91220KDF-ABx-117	120	87.1	14.8 A	9.7 %	17.6 %
MLX91220KDF-ABx-020	100	111.2	22.2 A	8 %	12 %
MLX91220KDF-ABx-025	80	111.2	27.8 A	7.5 %	11.5 %
MLX91220KDF-ABx-030	66.7	112.3	33.7 A	7 %	11 %
MLX91220KDF-ABx-050	40	111.2	55.6	4.2 %	6.2 %
MLX91220KDF-ABx-075	26.7	111.2	83.4	4 %	6 %
MLX91221KDF-ABx-010	120	100	10 A	9.7 %	17.6 %
MLX91221KDF-ABx-020	62.5	100.4	20.1 A	6 %	11 %
MLX91221KDF-ABx-120	62.5	140	28 A	6 %	11 %
MLX91221KDF-ABx-025	50	107.6	25.1 A	5.5 %	10.2 %
MLX91221KDF-ABx-038	33.3	112.6	42.8 A	5 %	10 %
MLX91221KDF-ABx-050	25	122	57 A	4 %	6 %
MLX91221KDF-ABx-075	16.7	122	85.6	4 %	6 %

Table 3 - OCD_{INT} threshold currents and accuracy limits for SOIC-16 versions

6. External Overcurrent Detection

6.1. Principle

The external OCD uses the voltage applied on VOC_{EXT} pin as threshold voltage. This translates into an overcurrent threshold in ampere depending on the sensitivity of the sensor. A voltage divider on VOC_{EXT} allows defining the threshold voltage in a custom way. Depending on the voltage divider configuration, the OCD_{EXT} can be used either in bidirectional or unidirectional mode. The External OCD threshold is defined within the measurement range of the sensor output. This feature is then suitable for out-of-range detection where the OCD threshold remains close to the nominal current. It offers a better accuracy than OCD_{INT} but the response is slower. The below table presents the unidirectional and bidirectional external OCD configurations.

<table>
<tr><th>Bidirectional configuration</th><th>Unidirectional configuration</th></tr>
<tr><td>
</td><td>
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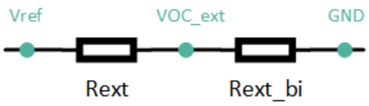
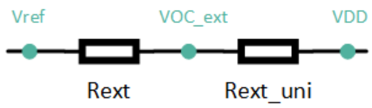
<tr><td>
</td><td>
</td></tr>
<tr><td>$$VOC_{EXT} = V_{REF} * \frac{R_{ext\_bi}}{R_{ext} + R_{ext\_bi}}$$
$$VLocd = VOC_{EXT}$$
$$VHocd = 2.V_{REF} - VLocd$$</td><td>$$VOC_{EXT} = V_{REF} + (V_{DD} - V_{REF}) * \frac{R_{ext}}{R_{ext} + R_{ext\_uni}}$$
$$VHocd = VOC_{EXT}$$</td></tr>
</table>

Table 4 -External OCD, bidirectionnal and unidirectional configurations

6.2. Application examples

Due to the current limitation of the reference pin a high impedance is needed on the input. **Thus $R_{ext} + R_{ext\_uni}$ or $R_{ext} + R_{ext\_bi}$ should be higher than 200 kΩ.**

Below are exposed some examples for external overcurrent detection. Calculations are made for VDD = 5 V. VREF = 2.5 V in the bidirectional configuration and VREF = 0.5 V in the unidirectional configuration.

Table 5: Configuration examples for external OCD

Current range [A]	Rext [kΩ]	Bipolar			Unipolar		
		Sensitivity [mV/A]	Rext_bi [kΩ]	**Thresholds [A]**	Sensitivity [mV/A]	Rext_uni [kΩ]	**Threshold [A]**
25	160	80	40	**±25**	18	40	**20**
25	300	80	20	**±29.3**	18	20	**23.4**
50	160	40	40	**±50**	9	40	**40**
50	160	100	100	**±31.3**	9	100	**25**

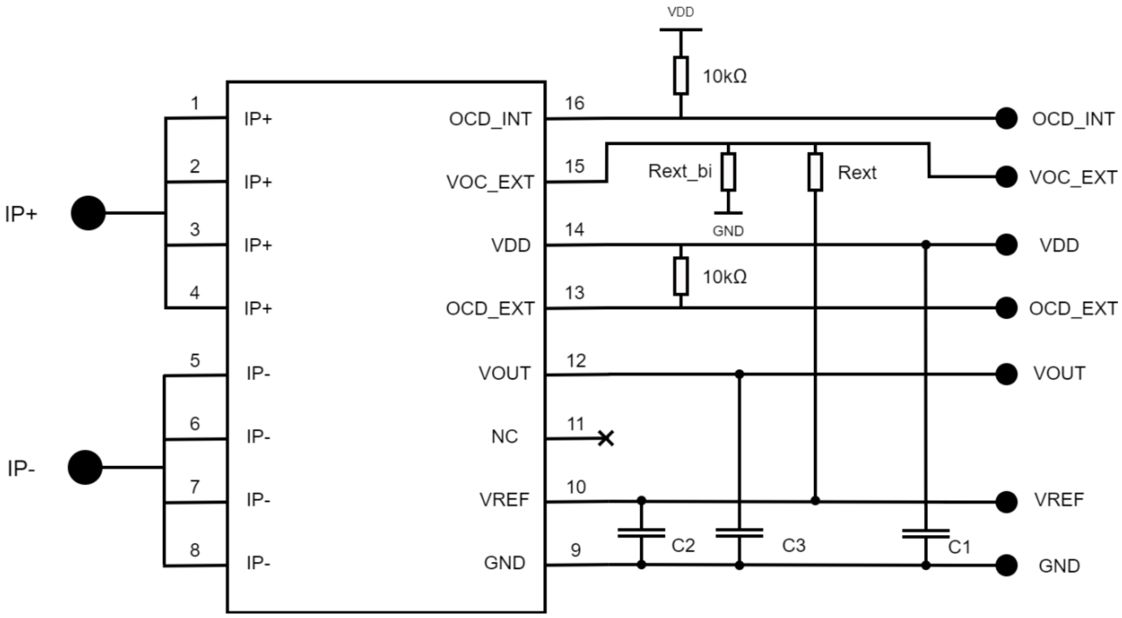


Figure 2: Recommended wiring for the MLX91220 with Bidirectionnal External OCD

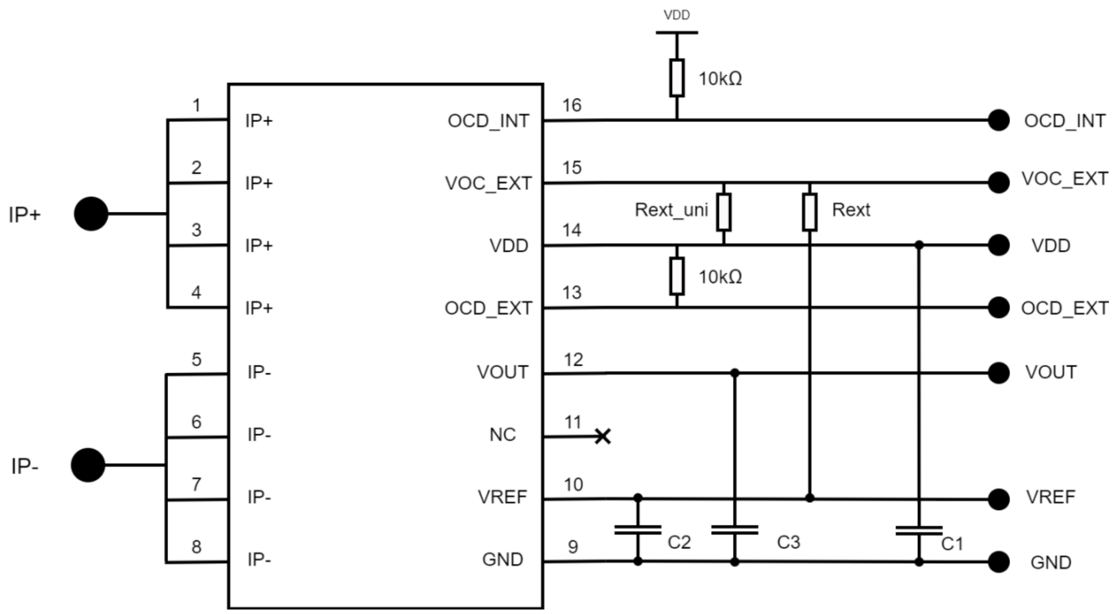


Figure 3: Recommended wiring for the MLX91220 with Unidirectionnal External OCD

6.3. Unidirectional OCD with bidirectional output

By default, when the sensor is programmed to have a bipolar output, the overcurrent detection is also performed bidirectionally. It means that there are two symmetrical detection levels VLocd and VHocd (cf. section 6.1 and 6.2).

It is still possible to have a bipolar current output for the application and have only one threshold $VHocd = VOC\_EXT$ for the overcurrent detection. To do so, it is needed to use the unipolar version of the sensor and an external reference voltage that is set either at 2.5 V (for MLX91220) or at 1.65 V (for MLX91221). Beware that in that case, the OCD threshold value will be on the positive current. If a threshold on the negative current is needed, the connection of IP+ and IP- should be inverted.

6.3.1. Unipolar current sensor

The polarity of the sensor is defined in the highlighted part of the product code: MLX9122xKDx-A**U/B**x-0xx. **U** stands for unipolar and **B** for bipolar. Please consult the datasheet for more information about the product code.

6.3.2. External reference voltage

If an external reference voltage is used, the signal should be buffered to overcome the reference current limitation on VREF. Please consult the application note on the Reference Pin AN91220_ReferencePin on www.melexis.com for more details on how to use an external reference voltage.

6.3.3. Configurations

Requested linear current	Requested Over Current	Ordering code	Reference	Value of reference	OCD thresholds

measurement range polarity (V_{OUT})	Detection (OCD_{EXT})	(ABx or AUF)	voltage	voltage	
Bipolar	Bidirectional	Bipolar-ABx	Internal	2.5 V (MLX91220) or 1.65 V (MLX91221)	Two thresholds (VLocd and VHocd)
		Bipolar-ABx	External	2.5 V (MLX91220) or 1.65 V (MLX91221)	Two thresholds (VLocd and VHocd)
Unipolar	Unidirectional	Unipolar-AUx	Internal	0.5 V	Single threshold VOC_{EXT}
		Unipolar-AUx	External	0.5 V	Single threshold VOC_{EXT}
Bipolar	Unidirectional	Unipolar-AUx	External	2.5 V (MLX91220) or 1.65 V (MLX91221)	Single threshold VOC_{EXT}

7. Chronogram

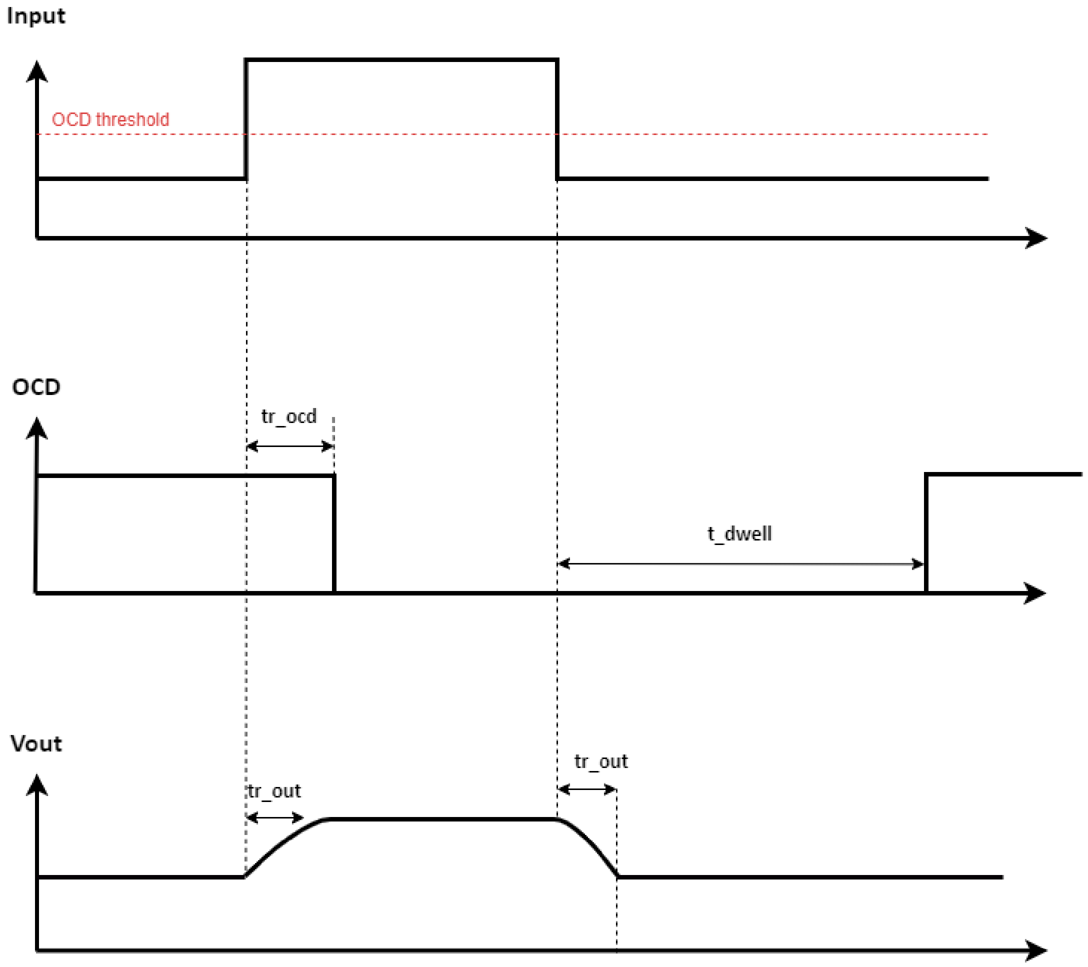


Figure 4: Chronogram showing over current detection behavior

Parameter	Description	OCD_int		OCD_ext
		Min	Max	Typ
tr_ocd	Response time of the overcurrent detection	1.4 µs	2.1 µs	10 µs
t_dwell	OCD output dwell time	10 µs		
tr_out	Response time of the analog output	< 2.4 µs		

8. Over Current Detection Behavior Around Threshold

When the primary current I reach the Over Current Threshold ($I_{THRESHOLD\_LOW}$) for OCD_{INT} or OCD_{EXT}, the expected behavior is to see the OCD pin to the ground.

In practice, there is a small current range (~1-2 A) where the OCD pin can be alternatively pulled-up and pulled-down. Above this range, the OCD pin will be constantly pulled-down to GND.

OCD_{EXT} threshold is determined by customer VOC level.

OCD_{INT} threshold provided in the Datasheet and this Application Note corresponds to $I_{THRESHOLD\_LOW}$ as it is essential to detect an overcurrent effect as fast as possible.

Current	Application effect
$I < I_{THRESHOLD\_LOW}$	OCD pin to VDD
$I_{THRESHOLD\_LOW} < I < I_{THRESHOLD\_HIGH}$	Transitionary area where OCD pin can be at VDD or GND
$I > I_{THRESHOLD\_HIGH}$	OCD pin to GND

Figure 5: OCD behavior around threshold value

9. OCD_{EXT} Behavior Around Threshold Value

OCD_{EXT} requires 10 µs (typ.) of Over Current to be triggered. After the end of the Over Current Effect, OCD_{EXT} pin has a dwell time of 10 µs. (cf. 7 Chronogram)

It is possible to observe a very short dwell time (300 ns) if the input current holds only for 9 µs. If the OCD mechanism at application level is fast enough, an Over Current can be detected already at 9 µs.

Two scenarios exist in terms of OCD_ext handling in light of the above described scenario of the 300 ns OCD_ext reporting:

1) OCD handler will not detect a 300 ns active low pulse

   From an application perspective, this is not problematic as this pulse will only occur if the OCD event has lasted more than 9 µs but not more than 10 µs. Since the overcurrent event has already disappeared, the OCD handler ignoring this OCD pulse does not represent a risk for the safety of the system.

2) OCD handler will trigger on the 300 ns active low pulse:

   The pulse only takes place when an overcurrent event has lasted for 9 µs, which means there has been an overcurrent event even though it has disappeared in the meantime. This is only 10% sooner than the typical 10 µs spec in place. Debouncing at the OCD handler can also be implemented to ignore this 300 ns pulse.

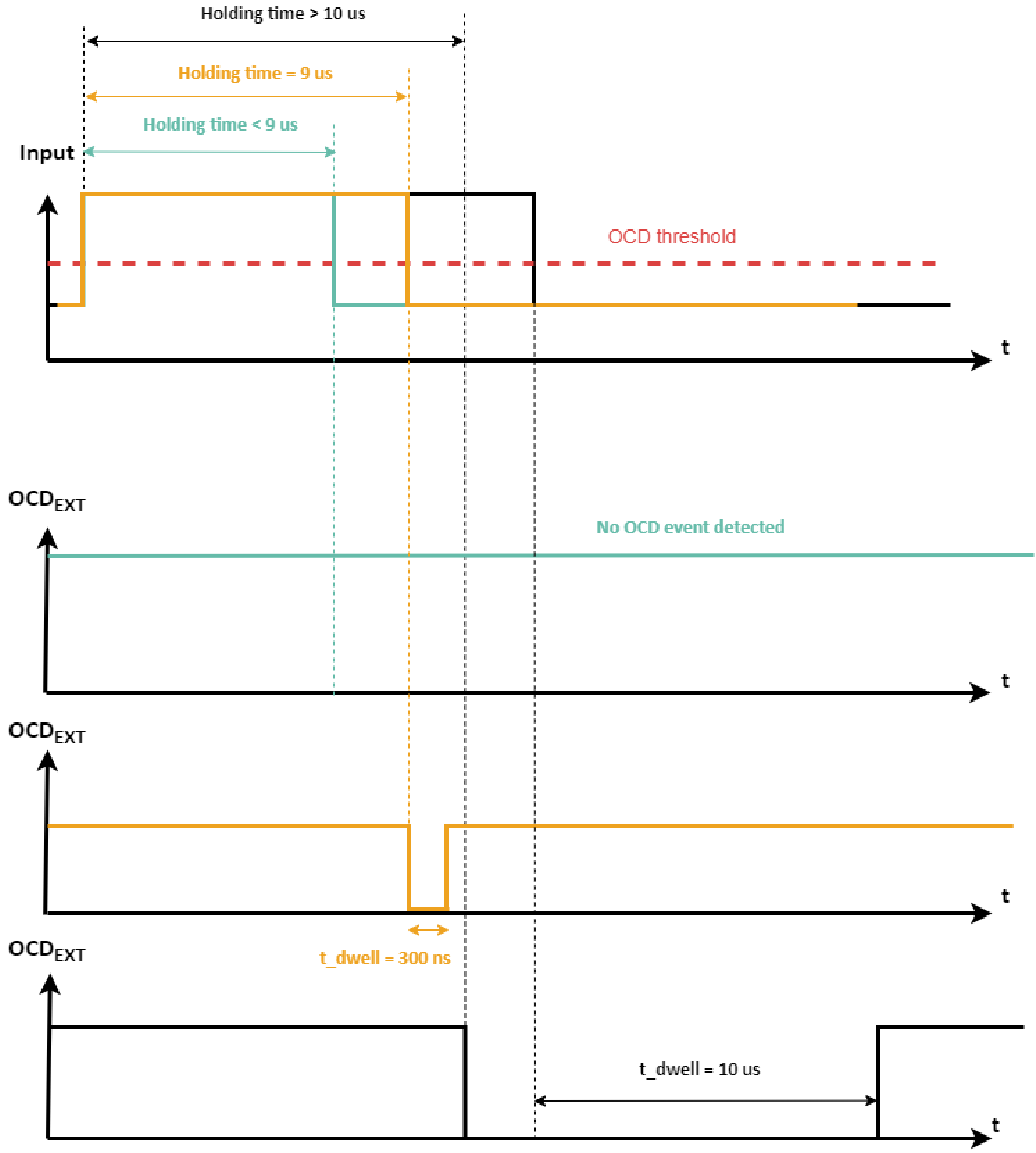


Figure 6: OCD$_{EXT}$ behavior for various input holding time

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11. Revision history table

Revision	Date	Description/comments
1.0	December 2020	Initial release