QEC-M-02 Local 24V Isolated I/O Timing Report, with LT238 & LT233H

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The following summarizes the behavior of the local 24V isolated I/O on QEC-M-02, with a clear mapping to DO (0→1), and comparison to LT238 (DO) vs. LT233H (DO) with LA212 (DI).

1) Purpose

The customer requested high-speed I/O timing characterization with emphasis on the **0→1 (rising-edge)** response.

Current configuration:

- QEC-M-02 uses a **Vortex86EX2** CPU, Master core clock: **533 MHz,** Slave core clock: **400 MHz**
- **DI:** LA212 photocoupler (24V isolated)
- **DO:** LT238 or LT233H Photo MOS-FET relay (24V isolated)

This report compares two DO device options used on the QEC-M-02 local 24V isolated output stage:

- **LT238 (DO)**

Transmission	Turn-On Time	T_{on}		0.25	0.35	ms	I_F=5mA, I_L=100mA,
	Turn-Off Time	T_{off}		0.02	0.05	ms	

- **LT233H (DO)**

Transmission	Turn-On Time	T_{on}		0.15	0.5	ms	I_F=5mA, I_L=100mA,
	Turn-Off Time	T_{off}		0.05	0.5	ms	

The **DI stage is kept identical (LA212)** to ensure the measured differences reflect DO device behavior, especially during **0→1** transitions.

- **LA212 (DI)**

Rise Time	tr		6		µs	Vce=5V, Ic=2mA,
Fall Time	tf		6		µs	RL=100Ω

Architecture:

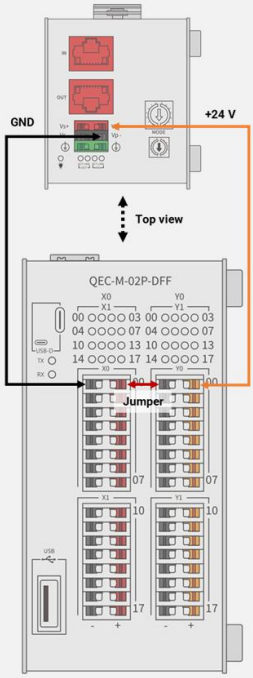
A loopback wiring method was used to validate the local 24V isolated I/O path under the same DI condition:

- Field power rails: +24V and +24V GND (0V)
- A short jumper (“loopback wire”) connects: QEC DO (Y00 / DQ) → QEC DI (X00 / DI)
- Initial condition: In setup(), DO is forced to LOW and held for stabilization before starting repetitive switching.

This makes the signal path:

EX2 GPIO OUT → LT238 or LT233H (DO stage) → external loopback → LA212 (DI stage) → EX2 GPIO IN

Diagram



With this wiring, when the DO turns on, the 24 V level is fed back into the DI input through the 1 kΩ resistor, forming a DO→DI loopback path on the on-board 24 V I/O.

2) Measurement (Rising-Edge 0→1)

The firmware repeatedly generates a **0→1** transition on the DO channel and confirms its arrival at the DI channel by polling.

This test is a **local 24V isolated I/O loopback** measurement (**DO→DI path**) with a known initial state.

Measurement flow (DO→DI, 0→1)

- Use EX2 `rdtsc` / `timer_GetClocks64()` to measure latency. At **533 MHz**, **1 tick ≈ 1.875 ns**.
  1. Force initial state: **Y00 = LOW** in `setup()` and wait for stabilization.
  2. Disable interrupts to reduce software jitter (`io_DisableINT()`).
  3. Timestamp **t0**.
  4. Set **Y00 = HIGH** (rising-edge 0→1).
  5. Busy-wait until **X00 == 1**.
  6. Timestamp **t1**.
  7. Compute **0→1 delay = t1 − t0**.
  8. Repeat and record min/max.

The measured value represents the local loopback propagation delay for the **0→1 rising edge**, including:

1. DO turn-on behavior (**dominant for 0→1**)
2. DI threshold crossing (LA212)
3. software polling detection granularity (minimized by tight loop + interrupts disabled)

Oscilloscope cross-check: A **Tektronix TDS2012C (100 MHz, 2 GS/s)** was used to observe the rising-edge waveform shape for cross-validation.

3) Results Summary (0→1 Focus)

Under room temperature (~25 °C) and standard 24V test conditions, the measured on-board 24V DO/DI timing is:

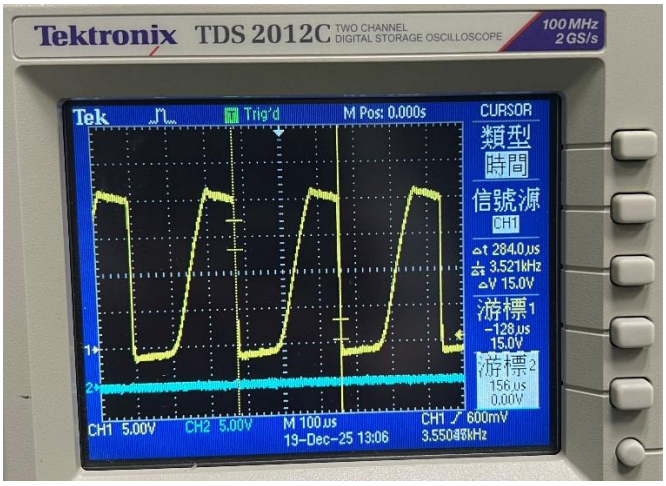
Measured propagation delay (µs)

Case	DO Device	DI Device	0→1 (ret01) Min	0→1 (ret01) Max	1→0 (ret10) Min	1→0 (ret10) Max
A	**LT238**	**LA212**	**206.6**	**244.5**	97.9	102.1
B	**LT233H**	**LA212**	**67.3**	**80.7**	90.9	94.2

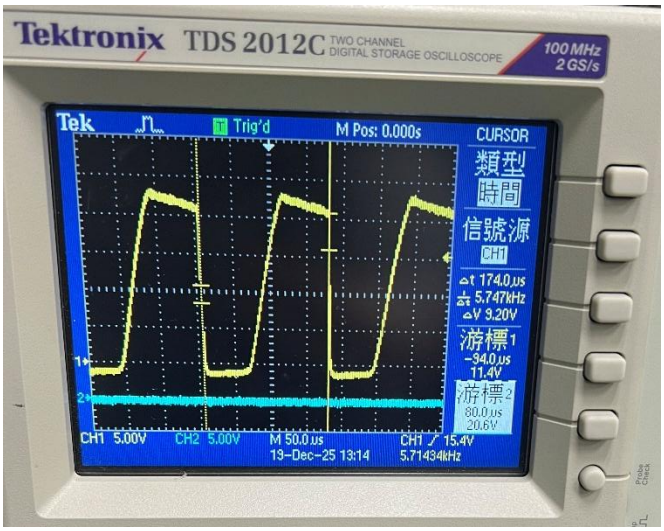
Key findings (Rising-edge 0→1)

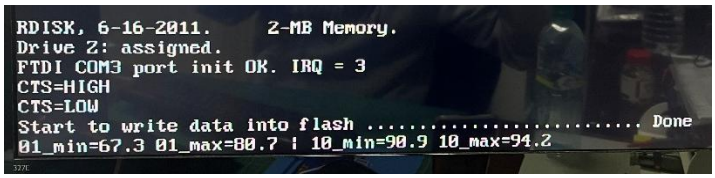
- **Dominant difference is the rising edge (0→1).**
  LT233H reduces the 0→1 delay by:
  - **Min improvement:** 206.6 − 67.3 = **139.3 µs**
  - **Max improvement:** 244.5 − 80.7 = **163.8 µs**
- **Jitter window (Max−Min) is also improved on 0→1.**
  - LT238: 244.5 − 206.6 = **37.9 µs**
  - LT233H: 80.7 − 67.3 = **13.4 µs**
- **Falling edge (1→0) is similar for both cases** (roughly **~91–102 µs** range) and is not the primary differentiator in this comparison.

A (LT238): Oscilloscope and firmware screenshot showing the 0→1 loopback delay range (**206.6–244.5 µs**) with LA212 DI fixed.



B (LT233H): Oscilloscope and firmware screenshot showing improved 0→1 loopback delay (**67.3–80.7 µs**) with LA212 DI fixed.





4) Conclusion / Recommendation

Based on the local 24V isolated I/O loopback measurement with:

- **LA212 as the fixed DI stage**, the **rising-edge (0→1)** propagation delay is the primary differentiator between the two DO devices.
- **LT233H achieves 67.3–80.7 µs**,
  whereas **LT238 measures 206.6–244.5 µs**,
  representing an improvement of approximately **139–164 µs** on the 0→1 edge under the same test conditions.
- The **falling-edge (1→0)** timing is comparable for both cases (~91–102 µs) and is not the limiting factor.

Therefore, LT233H is recommended for applications requiring a faster 0→1 response on QEC-M-02 local 24V isolated outputs, while maintaining the same DI device (LA212).