FINDING IRREGULAR EFFECTS IN CONTROL LOOP DESIGN WITHOUT COMPROMISE

Stable operation in all circumstances is essential for power converters. Different working conditions, such as load steps, startup/shutdown sequences and input voltage variation, apply to most converter types. In addition to the standard feedback control loop, integrated pulse width modulation (PWM) controllers provide extended functions, such as line feed-forward loop control and soft-start control. These extended control functions improve regulation for specific conditions. Such complex regulation systems require smart methods to ensure proper operation of the converter in all modes. For this task, extensive expertise and the right measurement tools are essential for identifying and locating unexpected events in the system.

Your task

A power converter's design and its stability need to be validated in all operational modes. Generally, PWM controllers provide multiple functions, which may increase complexity and therefore require a smart validation process. Examples include line feed-forward loop control and soft-start control.

Soft-start control is a specific mode: when the converter starts up, the positive duty cycle is gradually increased to ramp up the output voltage smoothly.

During this timeframe, the duty cycle varies from very low numbers to a higher value until the output voltage has reached a steady state condition. Once the sequence is complete, the standard control feedback loop regulates the output voltage to the target value. In addition, a line feed-forward loop might be active to optimize the output voltage regulation while the input voltage changes rapidly. Both control mechanisms coexist, making it difficult to detect and locate unexpected or unstable operation. Noise naturally exists in switching converter designs and may lead to improper regulation of the loop. Sudden instable loops can be detected by triggering on voltage variation or, better still, by monitoring the width of the positive duty cycle, since the duty cycle is used to regulate the power plant in order to keep the output voltage constant. A complex triggering capability is mandatory to detect any irregular event in such a complex control system.

Rohde & Schwarz solution

The MXO series oscilloscopes are perfect for this challenging task because they are based on digital trigger technology. The digital trigger provides a sensitive trigger of 0.0001 div and a resolution of up to 18 bit in high definition mode. Since two trigger conditions are essential to find variations of the positive duty cycle after the soft-start period has elapsed, complex trigger conditions can also be defined. Fig. 1 shows the trigger conditions at converter startup.

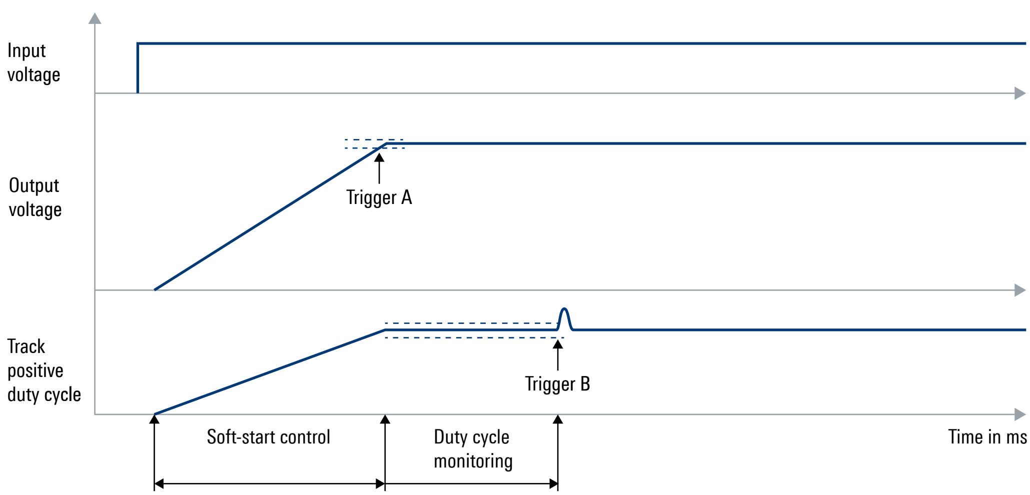
Trigger condition A is used to detect the end of the soft-start ramp and is configured as the window trigger, where the output voltage must be in a defined range. The type of the trigger for condition B must be width.

The width trigger will detect any values outside a defined range of the positive duty cycle. This can easily occur due to an improper design of the line feed-forward control filter. However, if the converter has a steady state, there will not be significant duty cycle variations. If the positive duty cycle deviates from a valid range due to some unexpected event, condition B will trigger and the acquisition will be stopped. This helps isolate this specific event and the user can discover the root cause of this irregular control event.

Application

A DC/DC switching converter in full bridge topology with synchronous rectification showcases the complex trigger functionality. The isolated converter operates at a switching frequency of 100 kHz and converts 48 V input voltage to 12 V output voltage. The output current is set to 8 A maximum. The digital controller used in this application enables the user to activate, deactivate and modify the line feed-forward control.

Fig. 1: Complex trigger definition to detect irregular effects



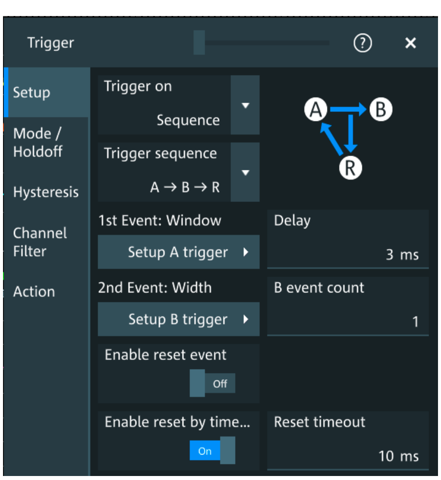


Fig. 2: Trigger sequence window

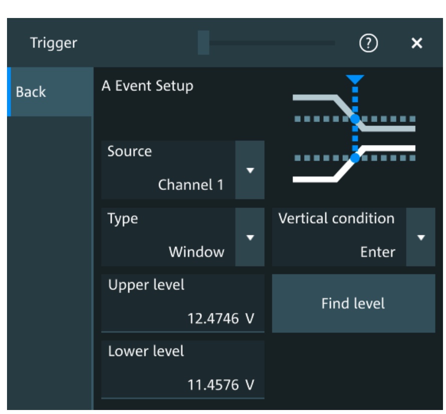


Fig. 3: Trigger event A window

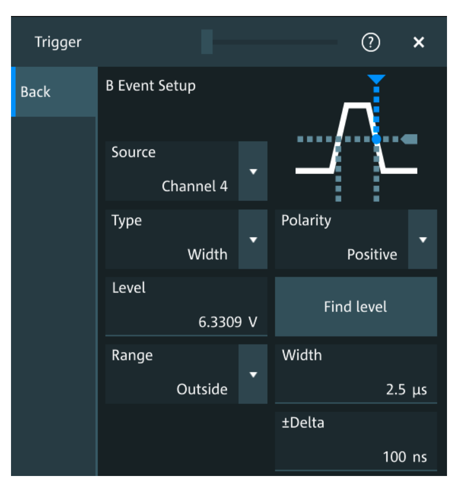


Fig. 4: Trigger event B window

Device setup

To configure a complex trigger:

- Set up a suitable channel, including proper probe selection
- Activate a trigger sequence and define an appropriate reset timeout (see Fig. 2)
- Define trigger A as window type, including upper and lower level, to catch the end of the soft start during startup (see Fig. 3)
- Activate the positive duty cycle measurement function and define the reference levels, e.g. 20/50/80 % of voltage
- Define trigger B as width type and set the width and delta time (see Fig. 4)
- Activate the duty cycle measurement function, including the track function

Measurement of the load transient

After being set up, the converter starts and the soft-start procedure is executed. As soon as the trigger detects a valid trigger for condition A, the instrument waits for any variation in the duty cycle measurement. Assuming a constant load after the soft start, the instrument will not trigger at condition B because the duty cycle should remain constant.

To showcase this complex trigger sequence, the line feed-forward function was activated inside the controller of the converter with an improper digital filter design. As a result, the instrument also triggered at condition B. The recorded measurement is shown in Fig. 5, where the output voltage is measured on channel 1 and the input voltage is measured on channel 3. Channel 2 shows an internal signal of the controller, which reflects the input voltage to the secondary side. The M2 channel shows channel 2 filtered by a lowpass filter. Furthermore, the PWM control signal (channel 4) and the track waveform of the positive duty cycle are displayed in the bottom window.

3 ms after the soft-start sequence has elapsed, the instrument triggers at condition B, because the duty cycle shows a positive step followed by a negative drop. This duty cycle variation is only present when the line feed forward is activated. The next step would be to optimize the acquisition length, which is now possible due to the complex trigger sequence. The result is shown in Fig. 6.

In this case, more details become visible with increased accuracy, giving the user a better understanding of the system. Now, the user may start the process and can find the root cause very efficiently.

Fig. 5: Startup of the converter and irregular control effects

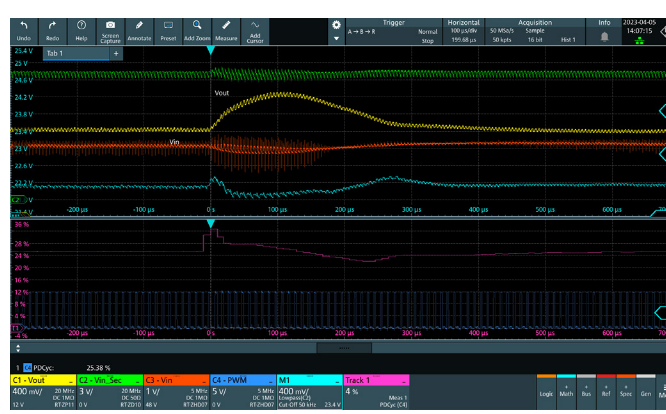


Fig. 6: Irregular control effects at trigger condition B

Summary

The MXO series oscilloscopes are ideal for identifying irregular events in the control loop of power converters. Their digital trigger technology enables the user to define complex trigger events to isolate the root cause efficiently. Furthermore, the large memory allows the user to add additional functions, such as the track on duty cycle, where a high sample rate is required over a long acquisition time. The instrument's capabilities are ideally suited to validating and understanding the operation of power converter designs.

See also

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