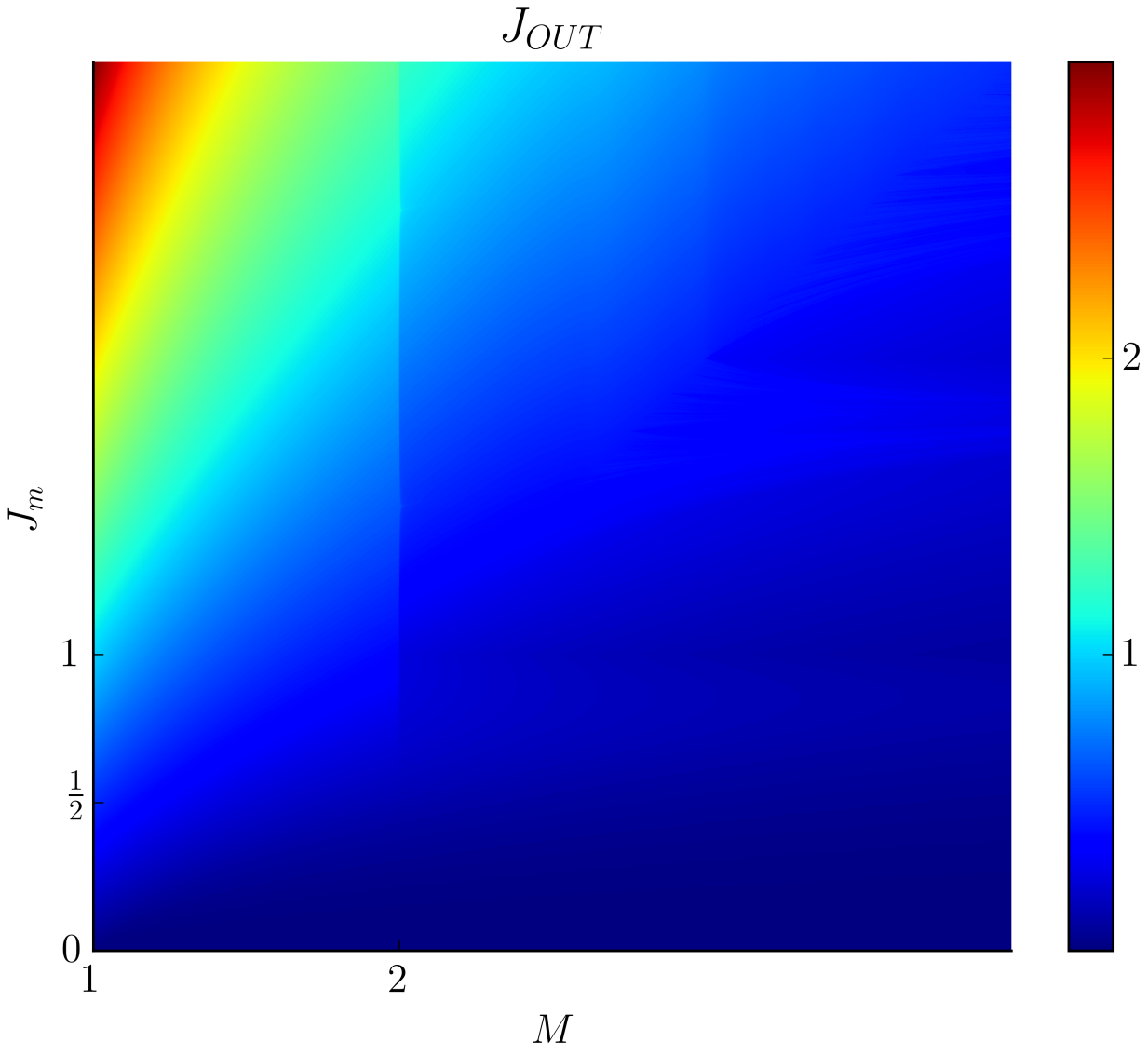
Experimental Verification of a Peak Limiting Current Mode Controlled Switching Cell Model

Marija Glišić and Predrag Pejović

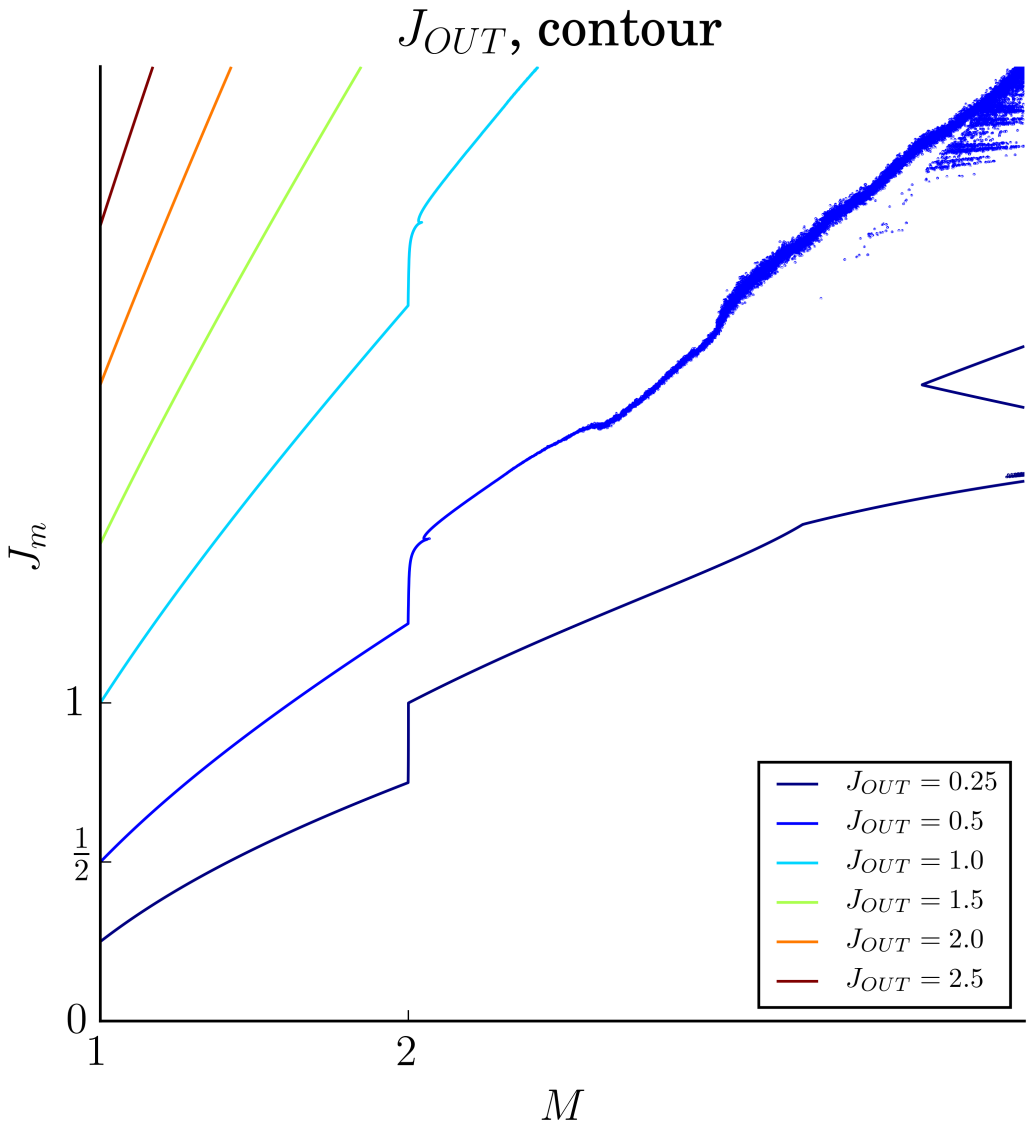
Introduction

- peak limiting current mode control ...
- subharmonic instability for $D > 0.5$
- what happens for $D > 0.5$?
- unstable period-1 limit cycle, but after that?
- recent results, primarily theoretical ...
  1. infinite number of DCMs
  2. zone where DCMs occur
  3. zones of period-k DCMs
  4. dependence of I_{OUT} on I_m
- **does this really happen?**
- experimental verification in this paper ...
- using a boost converter ...
- switching cell approach, 1-st order dynamics ...

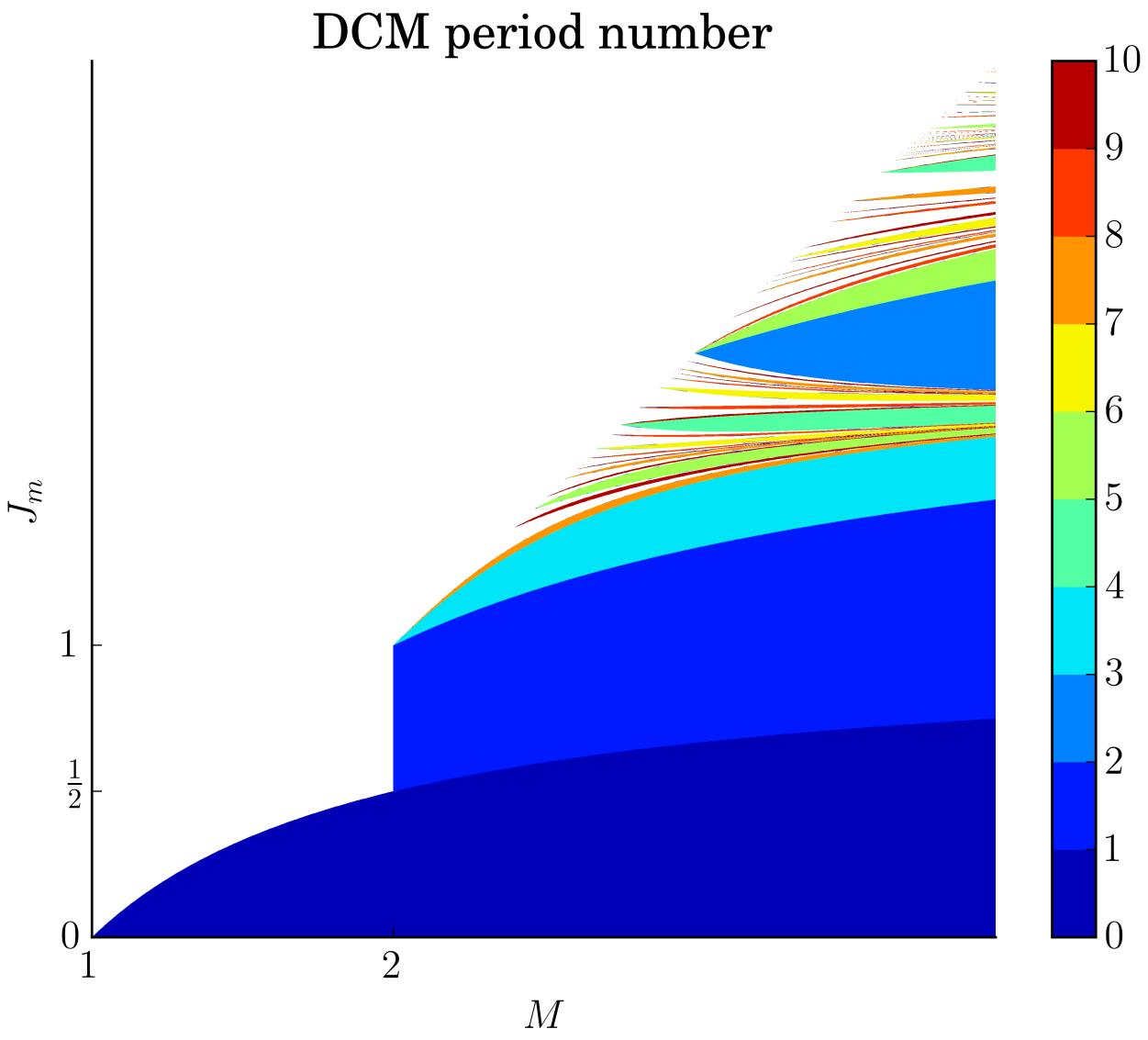
Predictions, J_{OUT}



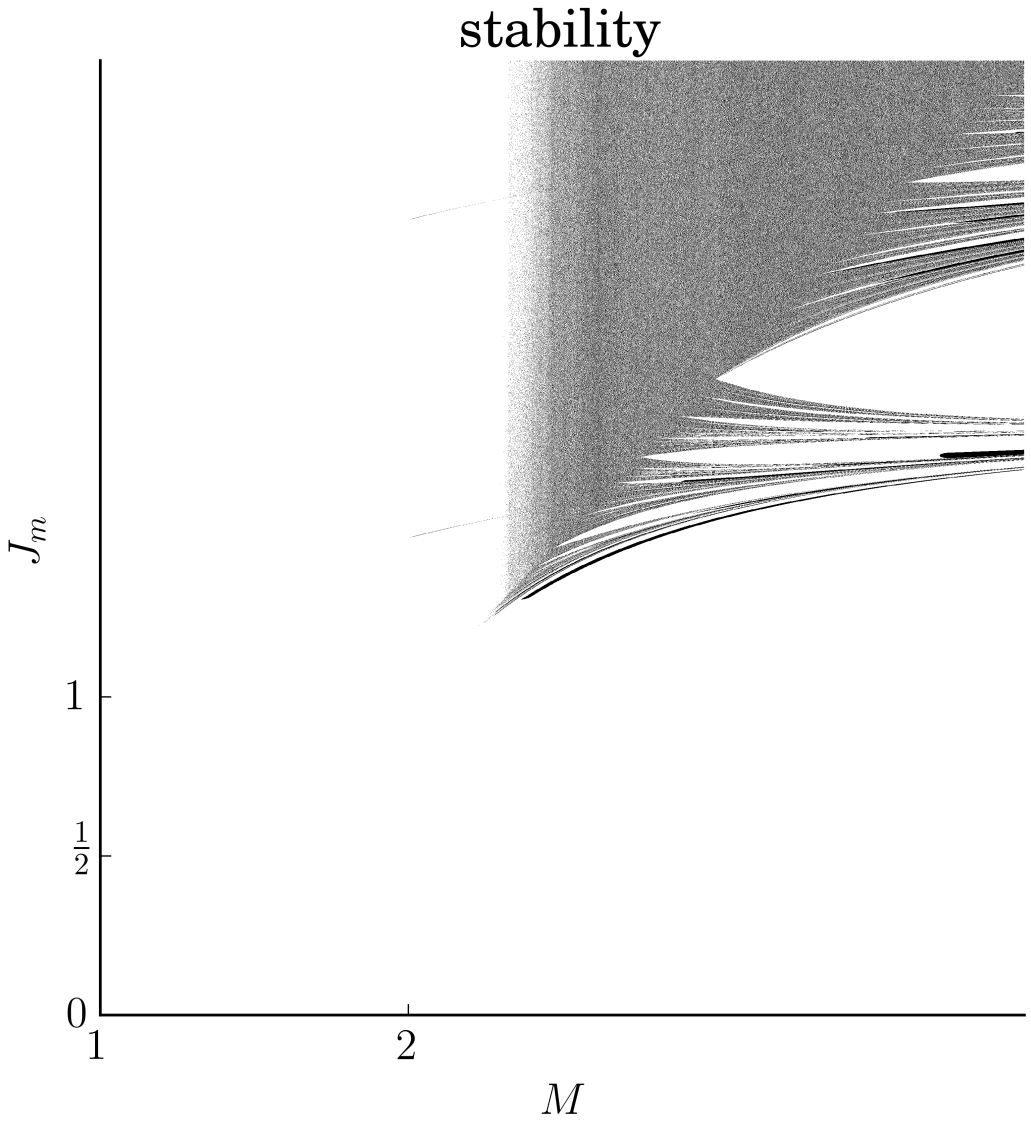
Predictions, J_{OUT}



Predictions, Period Number



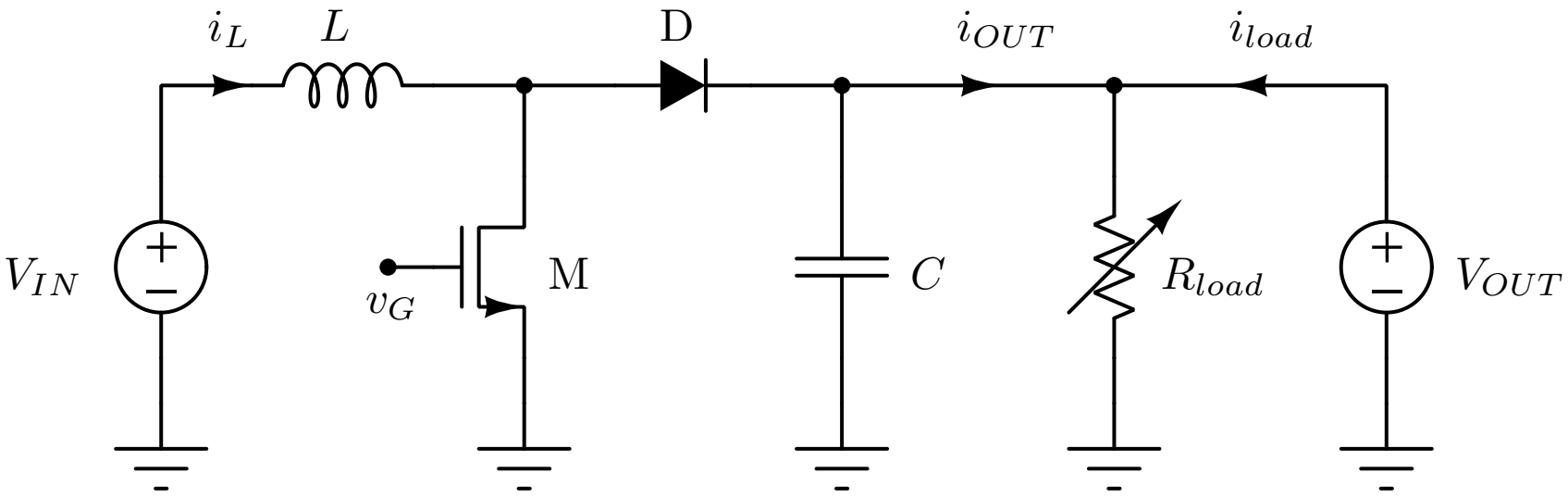
Predictions, Stability



Hypotheses to be Verified

1. verify dependence of the switching cell output current on the peak value of the inductor current
2. verify existence of higher period number discontinuous conduction modes

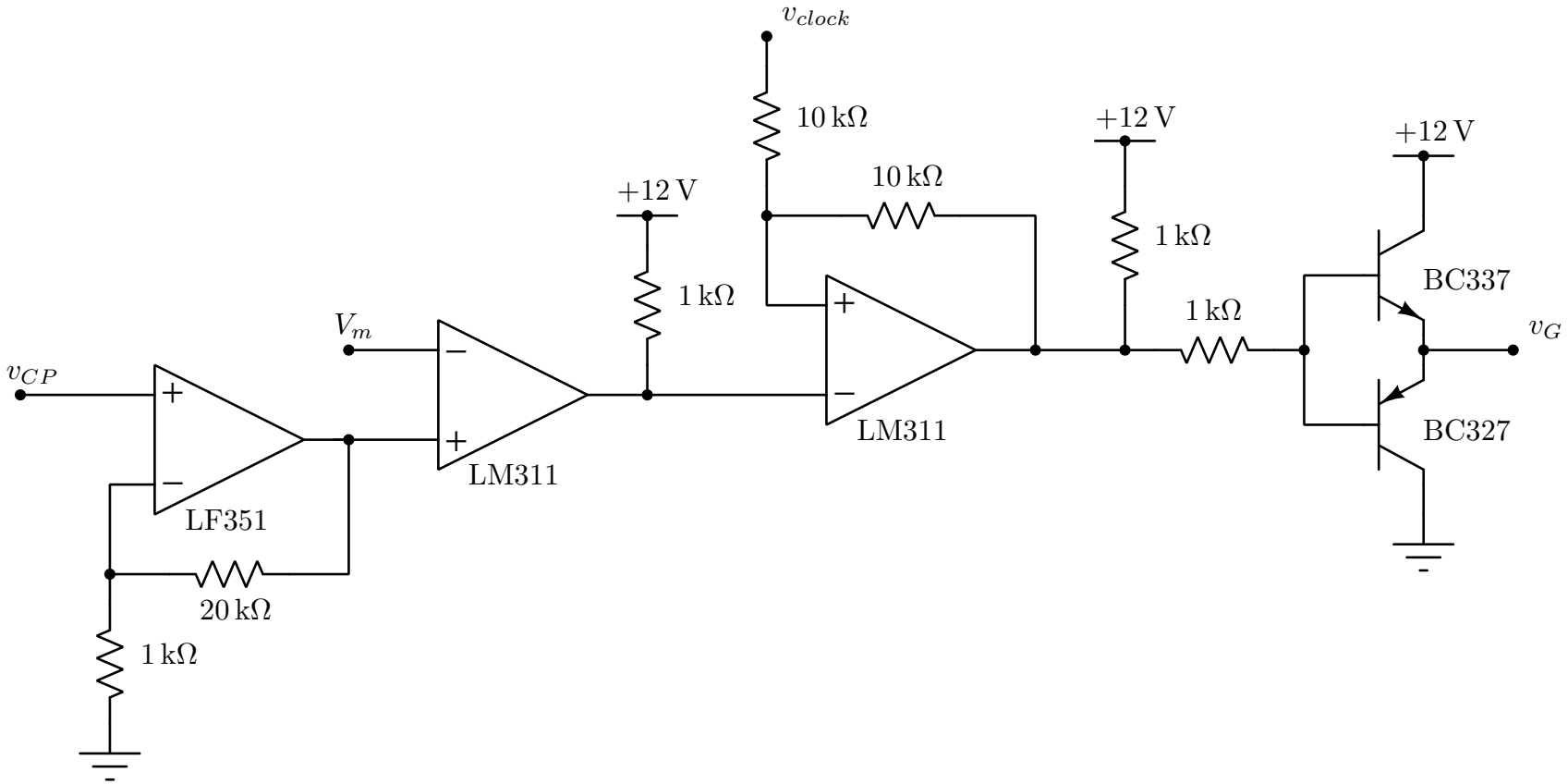
Experimental Setup: Power Part



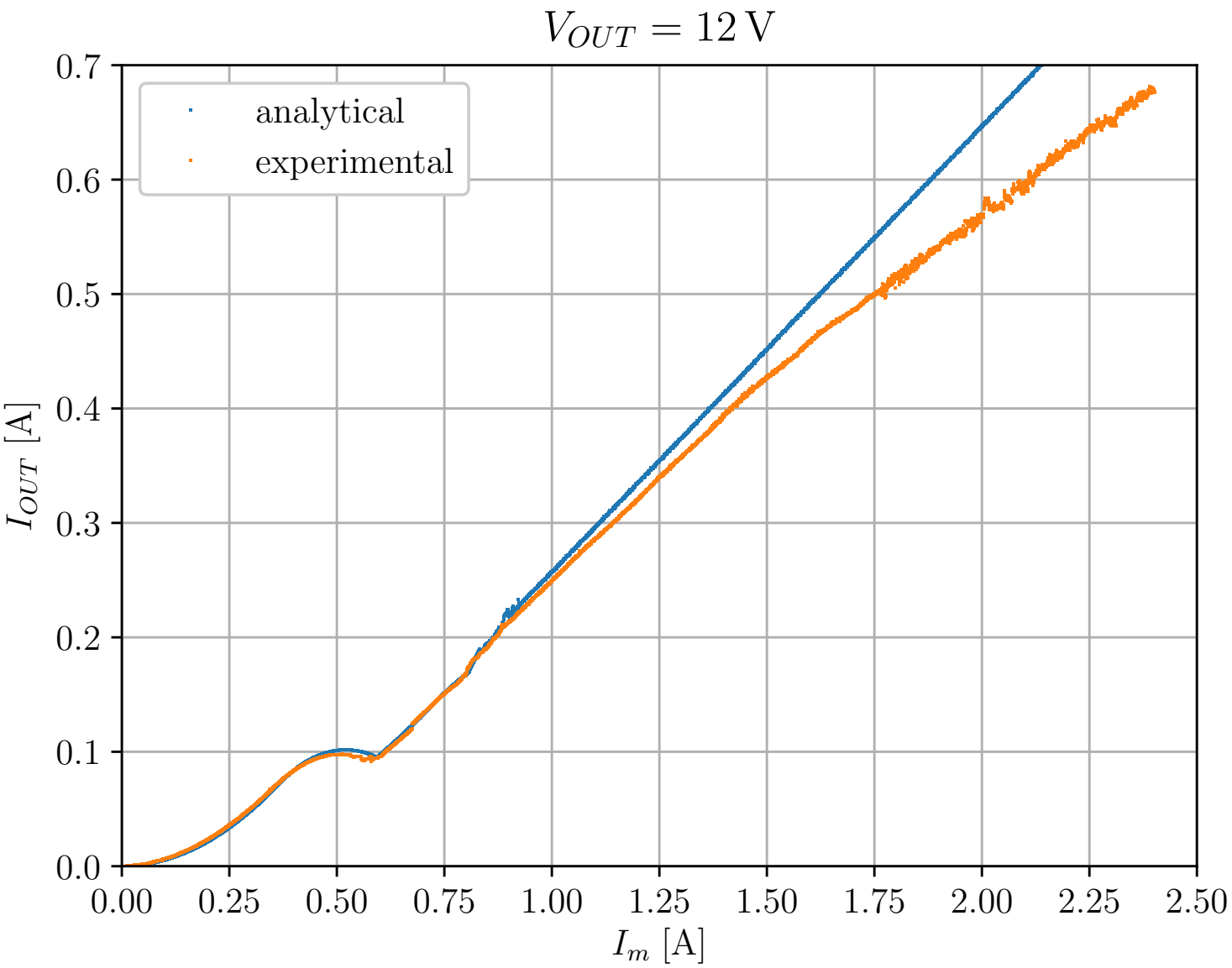
Experimental Setup: Power Part

- $V_{IN} = 5\,\mathrm{V}$
- V_{OUT} either $12\,\mathrm{V}$, $17\,\mathrm{V}$, $24\,\mathrm{V}$, or $29\,\mathrm{V}$.
- $0 < I_m \leq 2.5\,\mathrm{A}$ in 5000 data points
- Keysight 34461A to measure I_{OUT}
- Tektronix TBS 1052B-EDU to record waveforms
- Keysight 33500B to provide the clock
- Agilent 33220A to assign I_m
- Python to automate the measurements ...
- IRF1010N MOSFET
- 1N5819 diode
- $L \approx 1\,\mathrm{mH}$

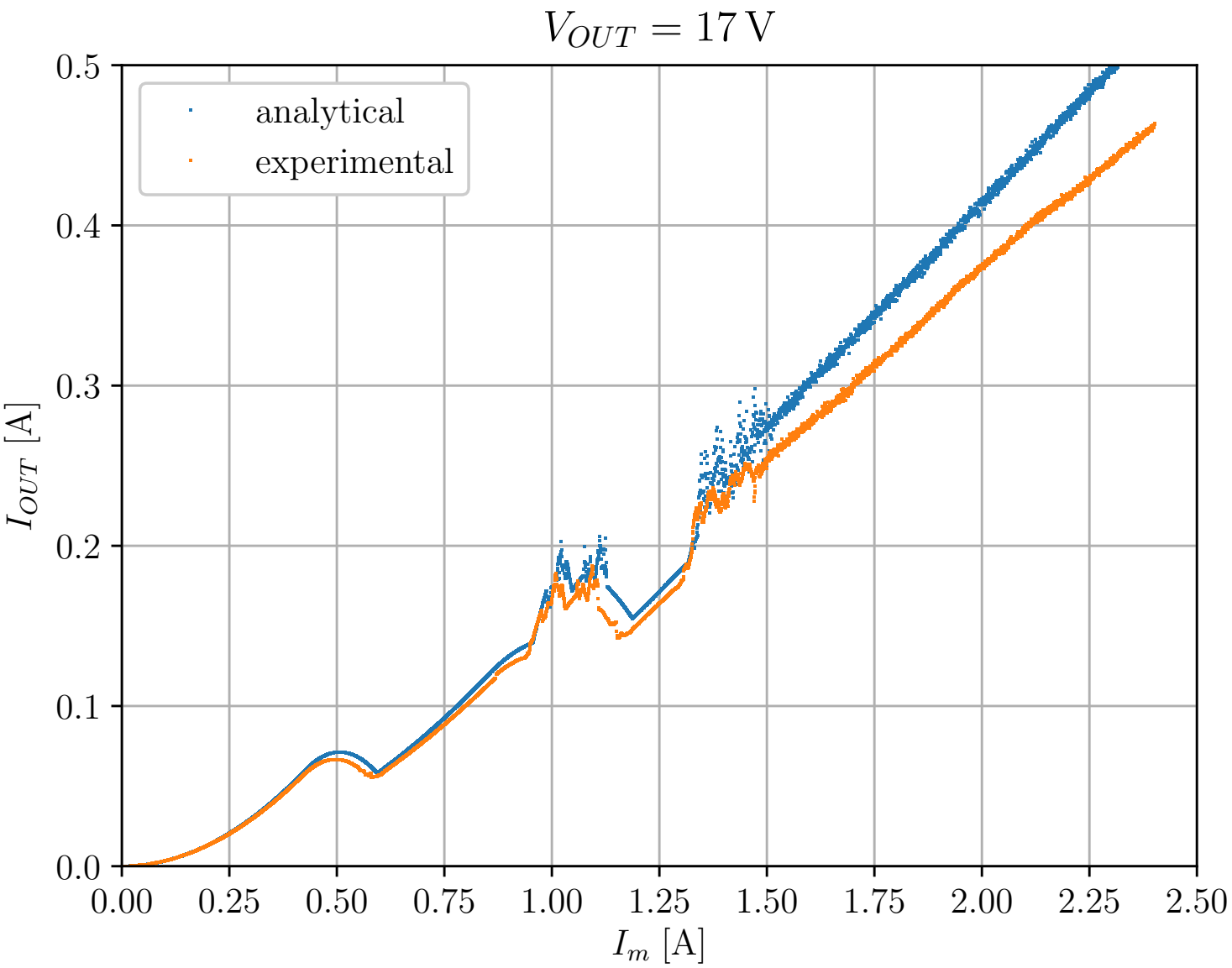
Experimental Setup: Control Part



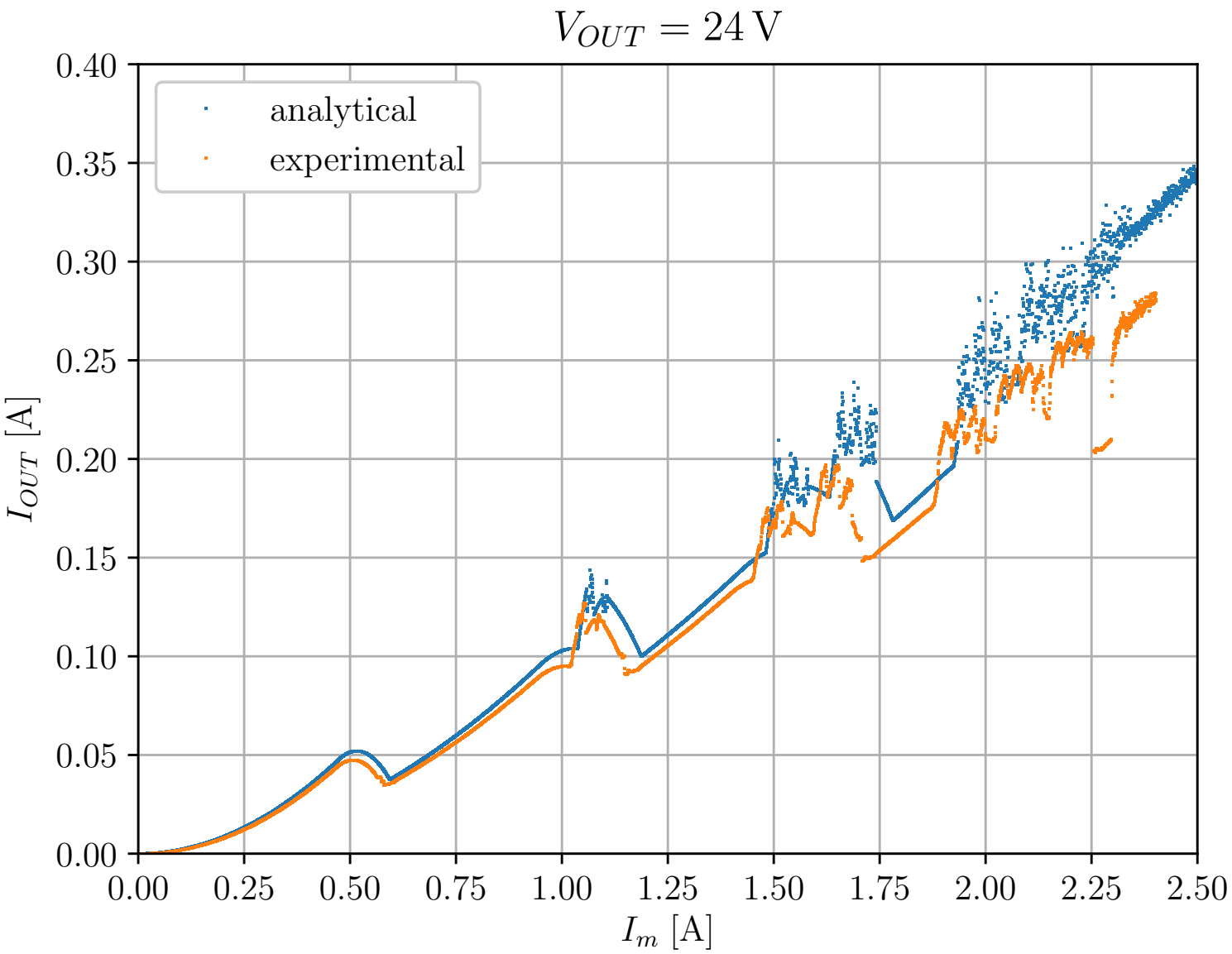
Output Current, $V_{OUT} = 12\,\mathrm{V}$



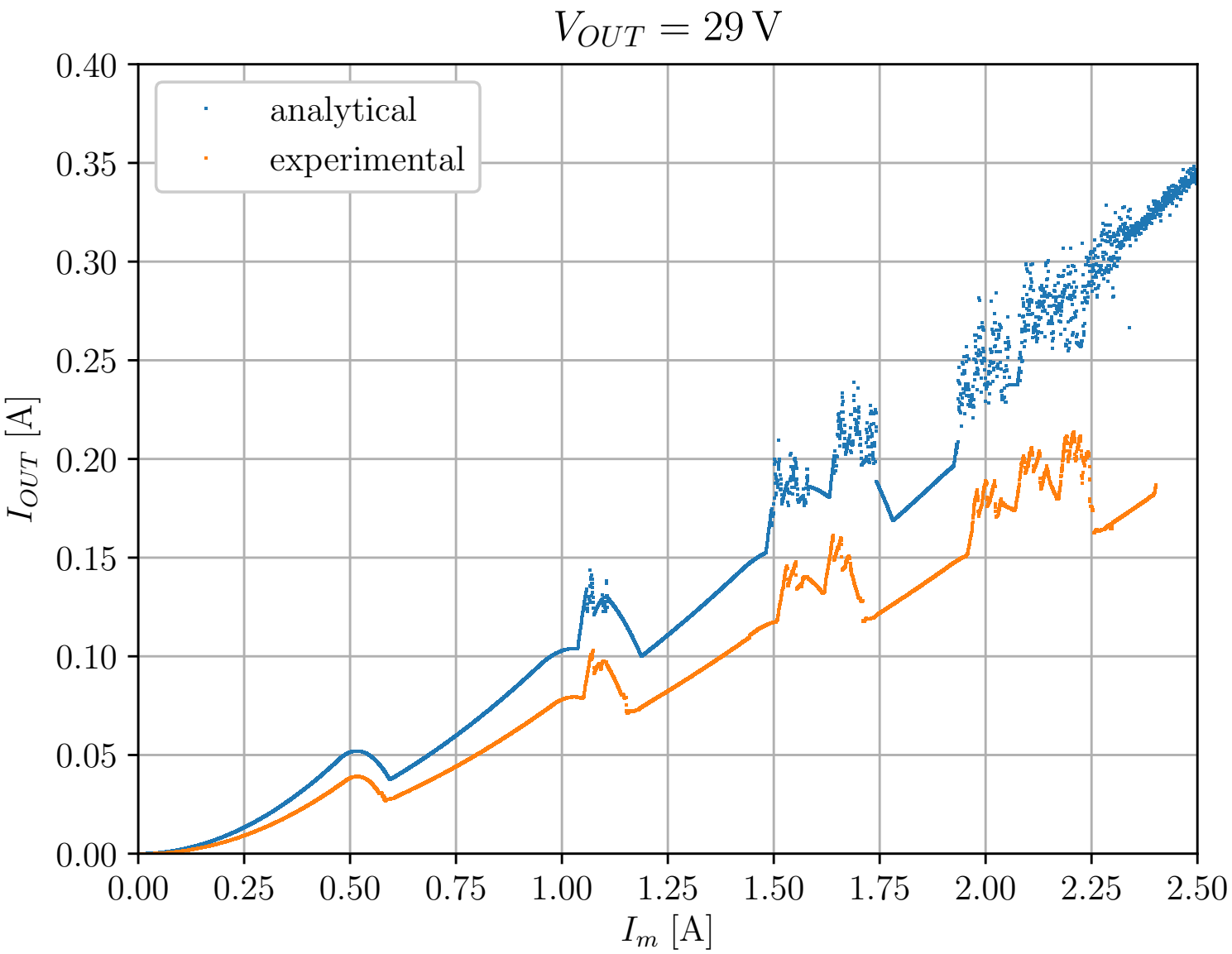
Output Current, $V_{OUT} = 17\,\mathrm{V}$



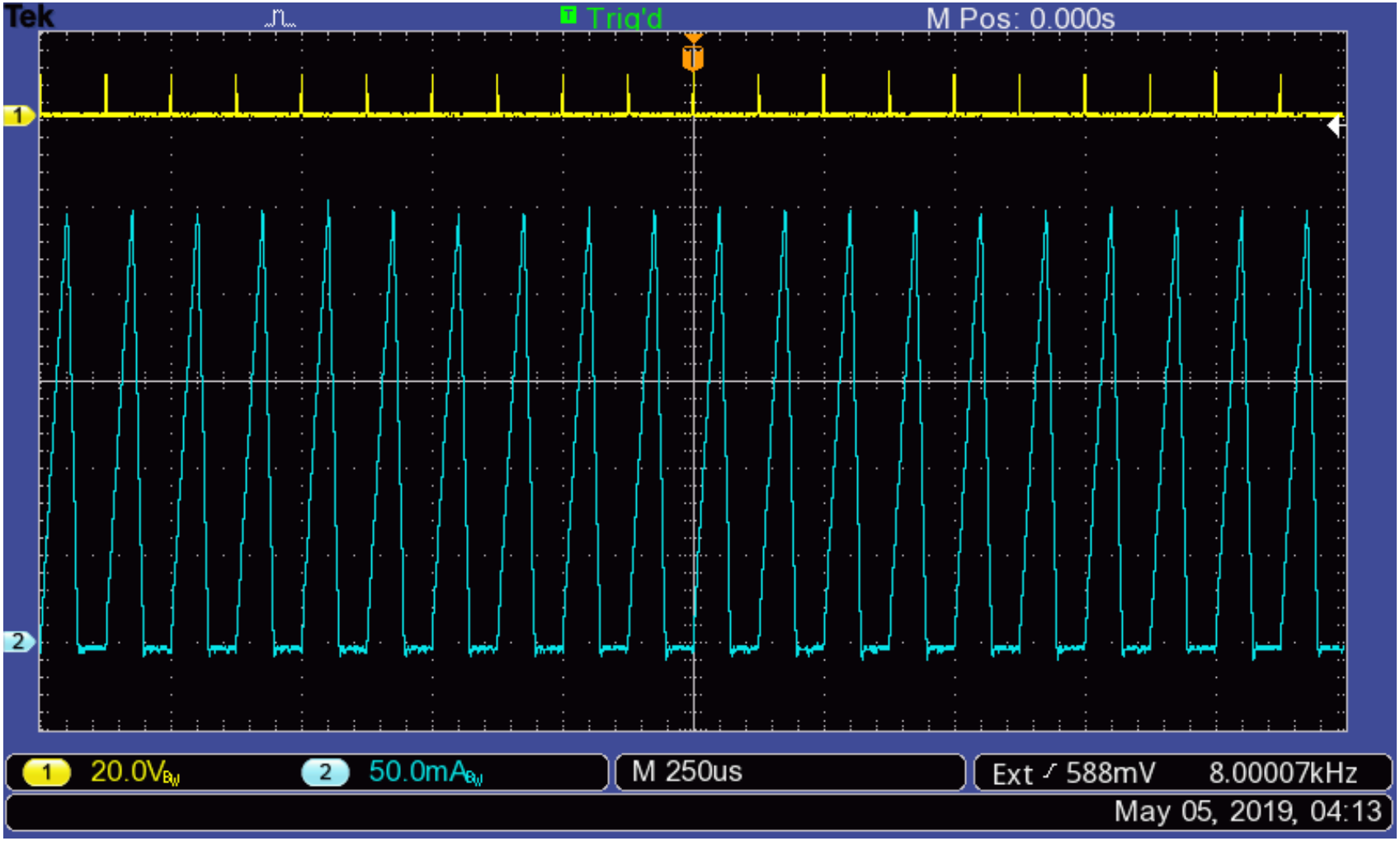
Output Current, $V_{OUT} = 24\,\mathrm{V}$



Output Current, $V_{OUT} = 29\,\mathrm{V}$

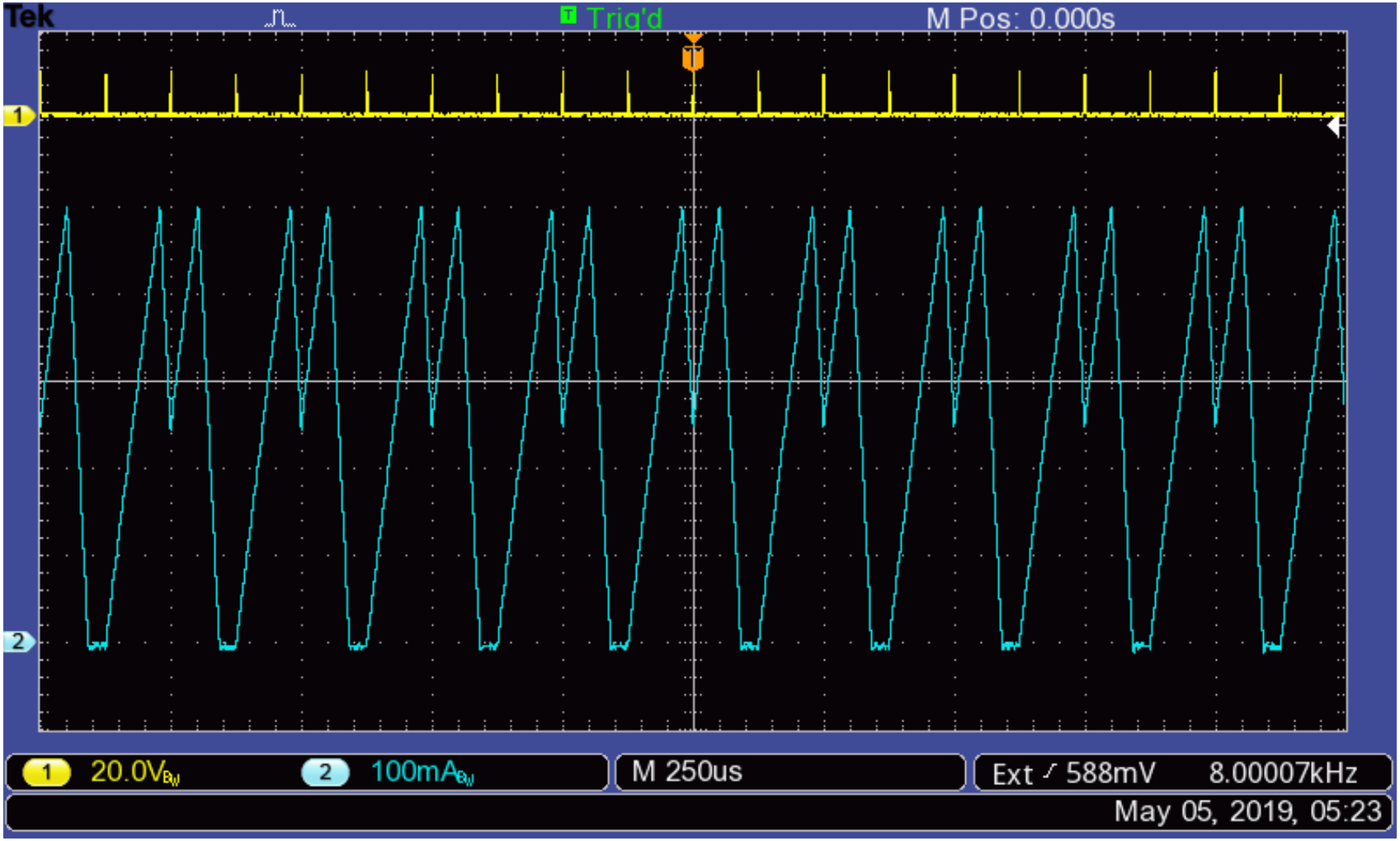


Period-1 Operation



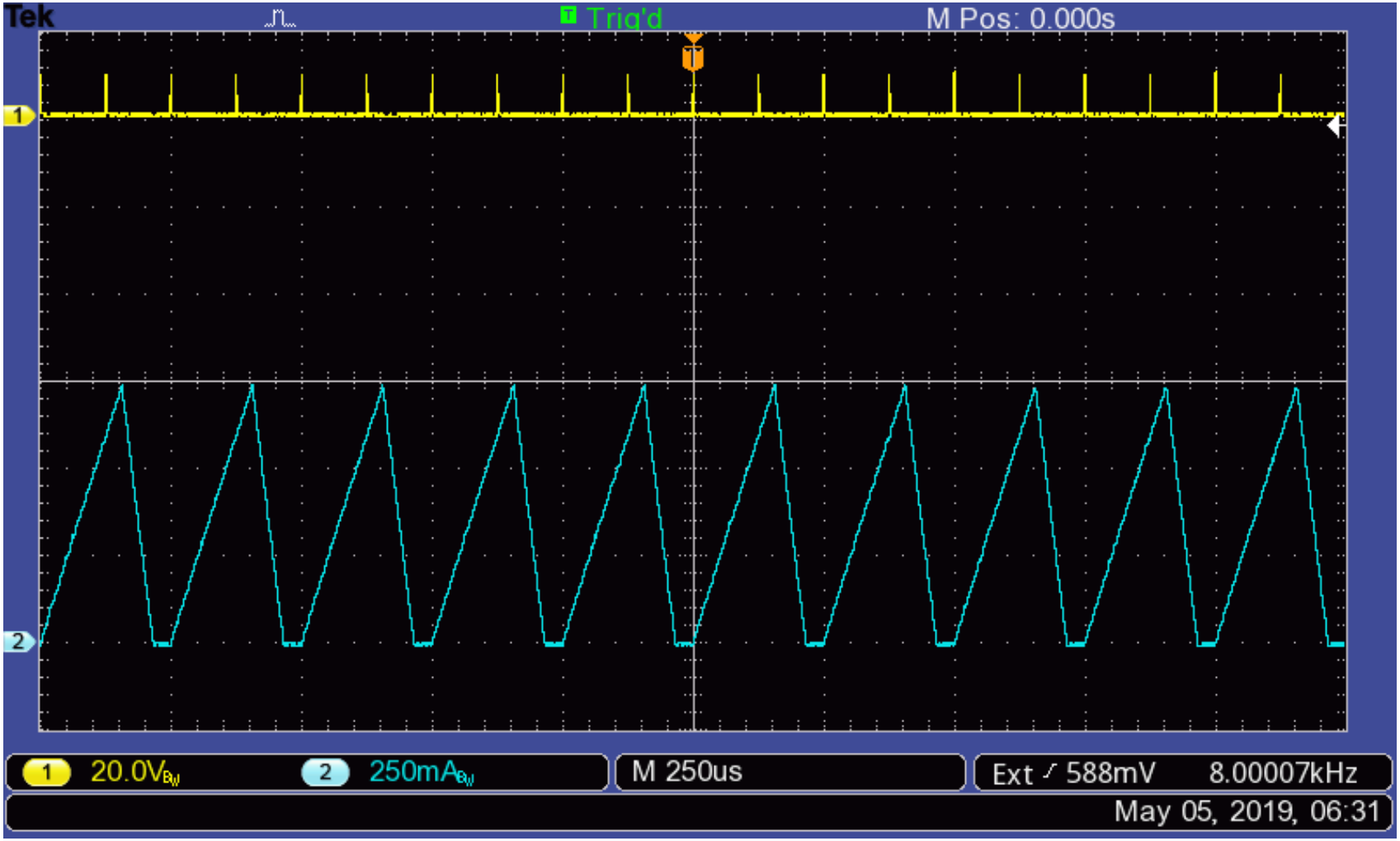
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 237.82\,\mathrm{mA}$$

Period-2 Operation



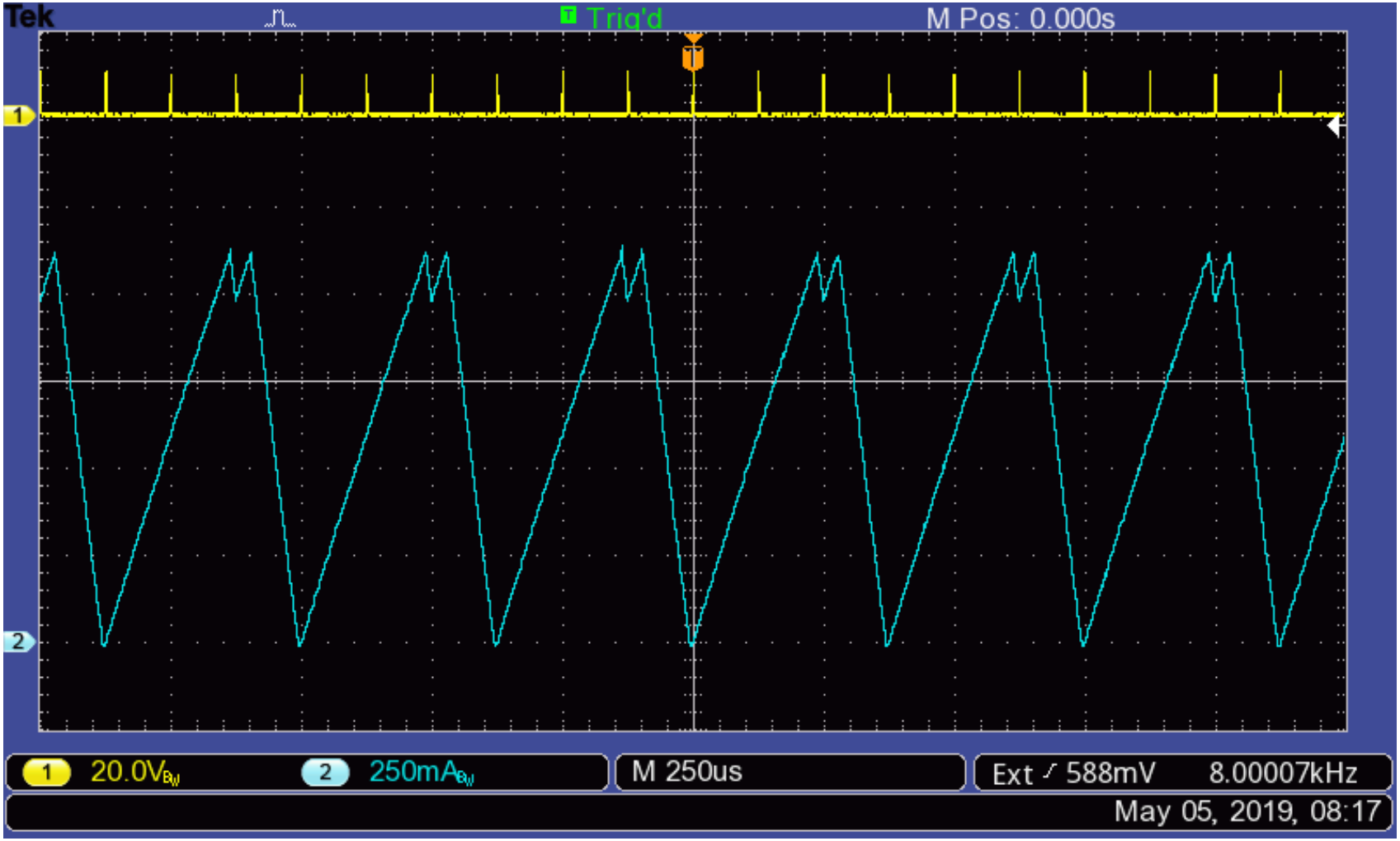
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 488.60\,\mathrm{mA}$$

Period-2 Operation



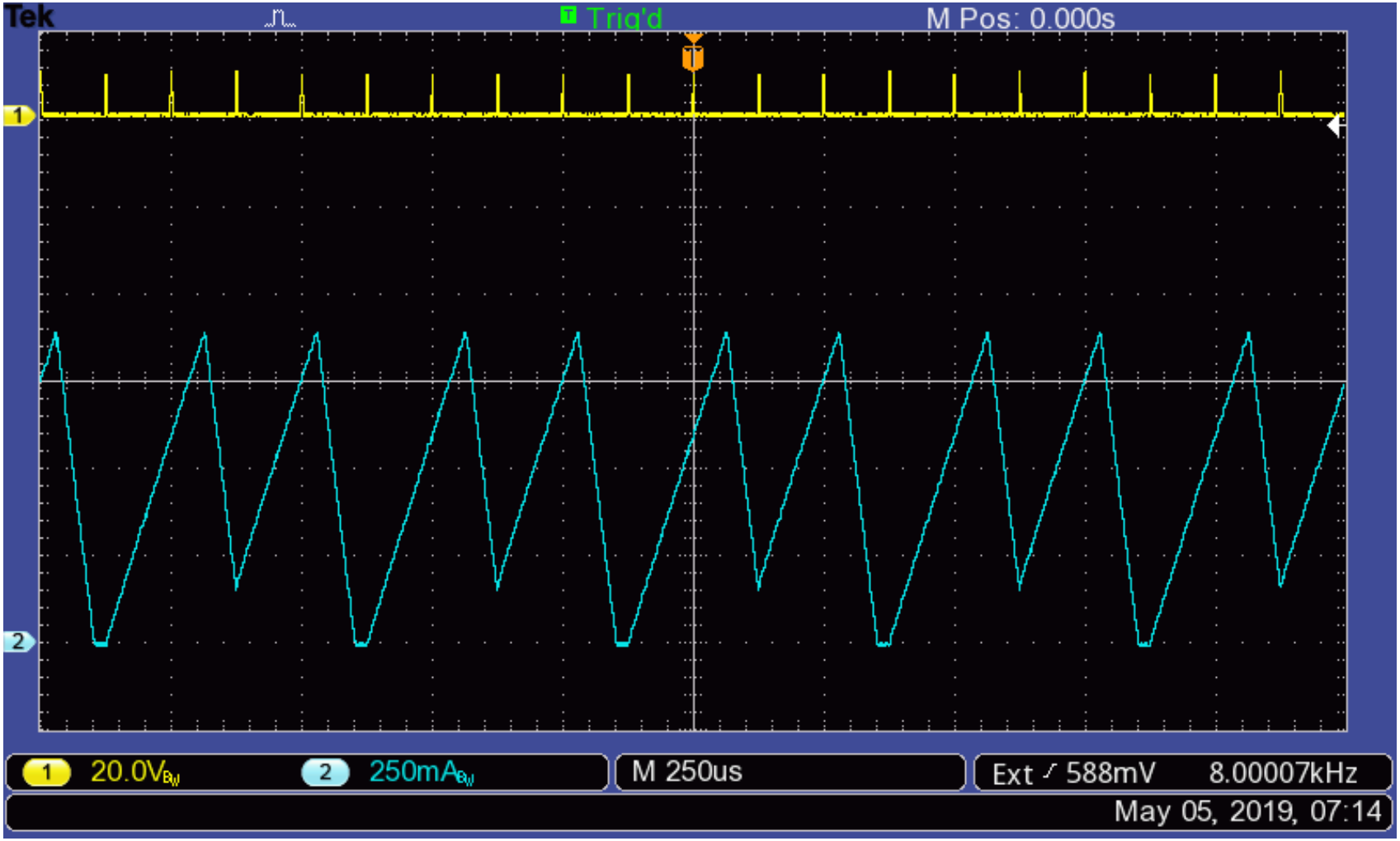
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 732.67\,\mathrm{mA}$$

Period-3 Operation



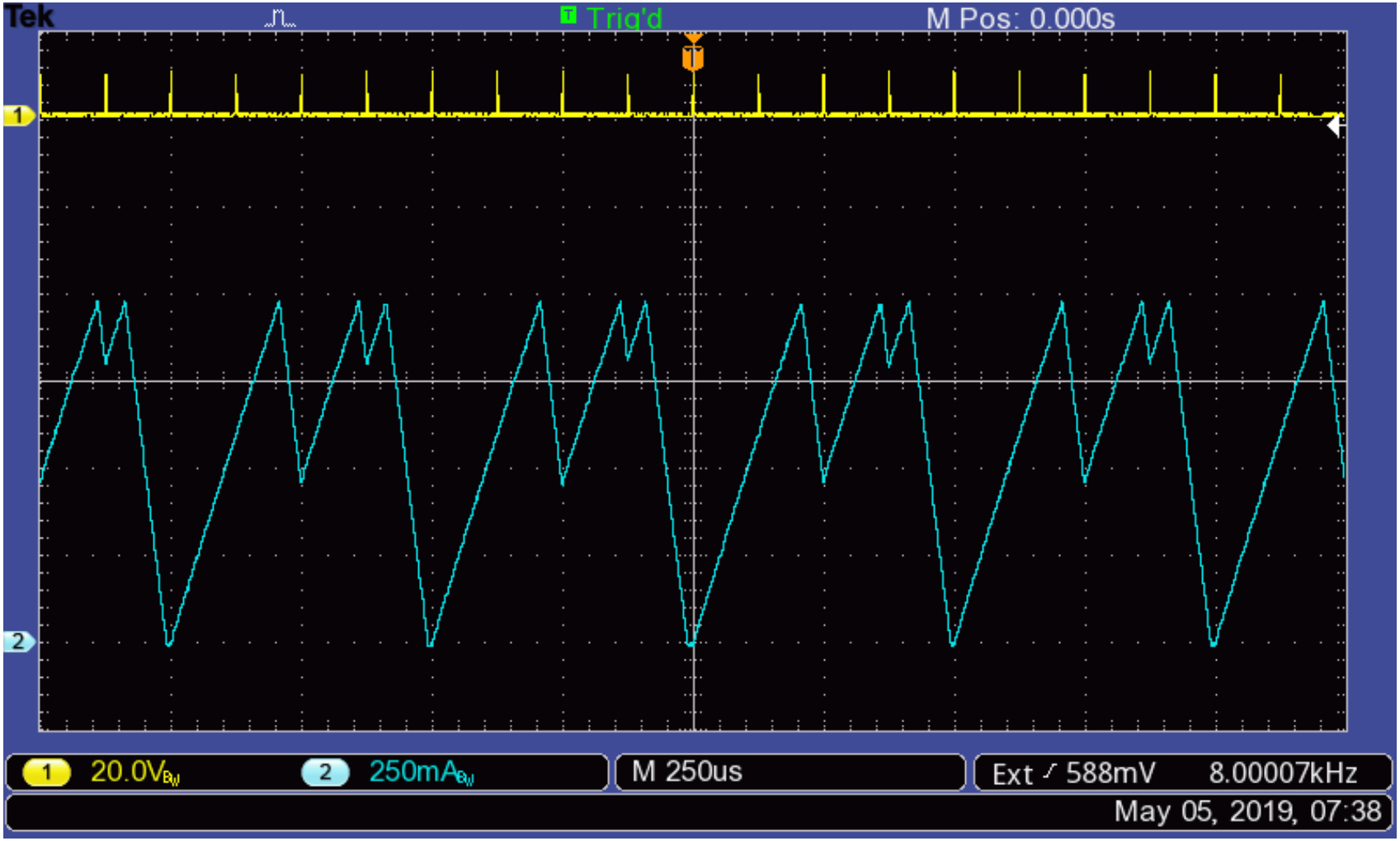
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 1115.09\,\mathrm{mA}$$

Period-4 Operation



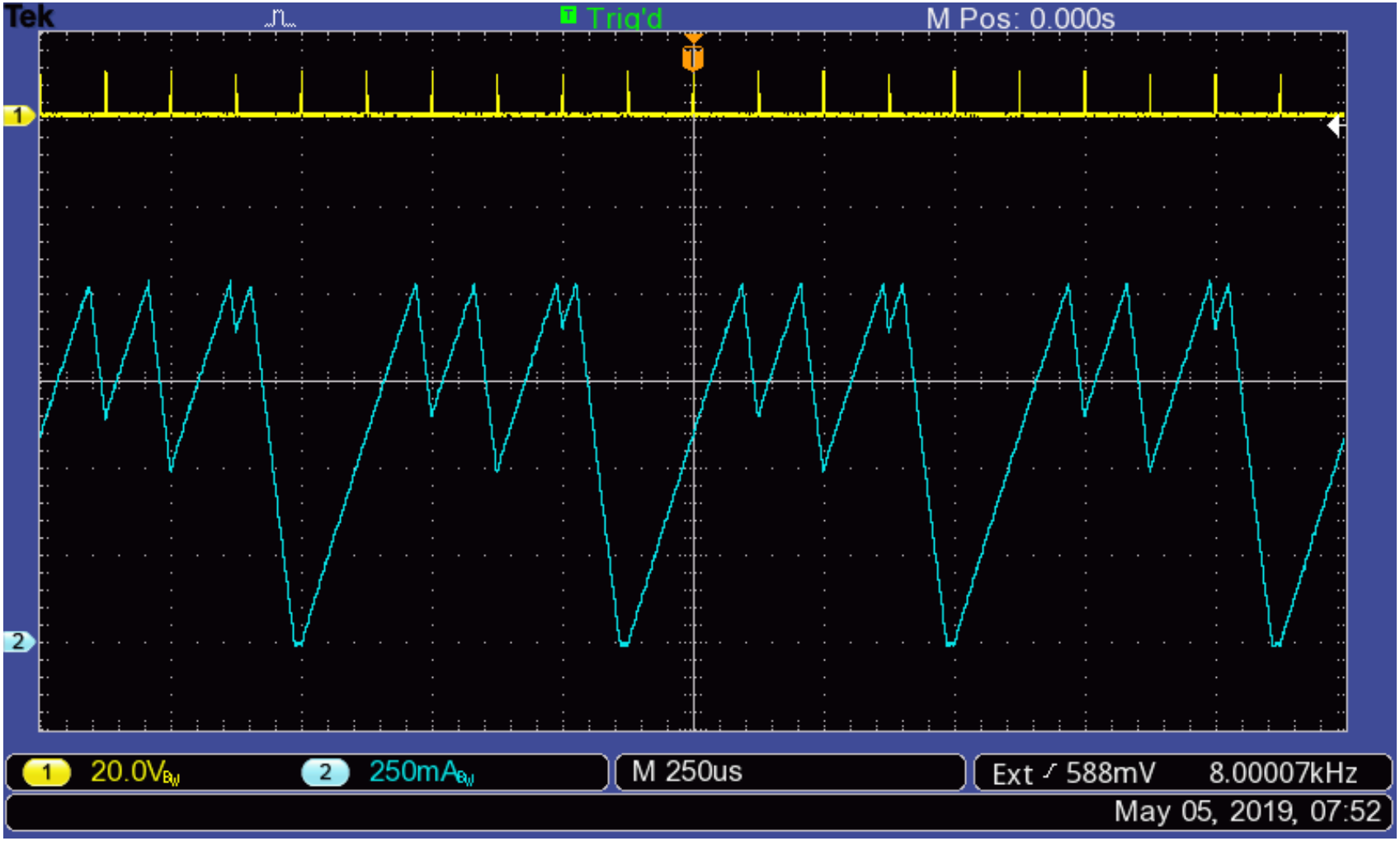
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 888.81\,\mathrm{mA}$$

Period-4 Operation



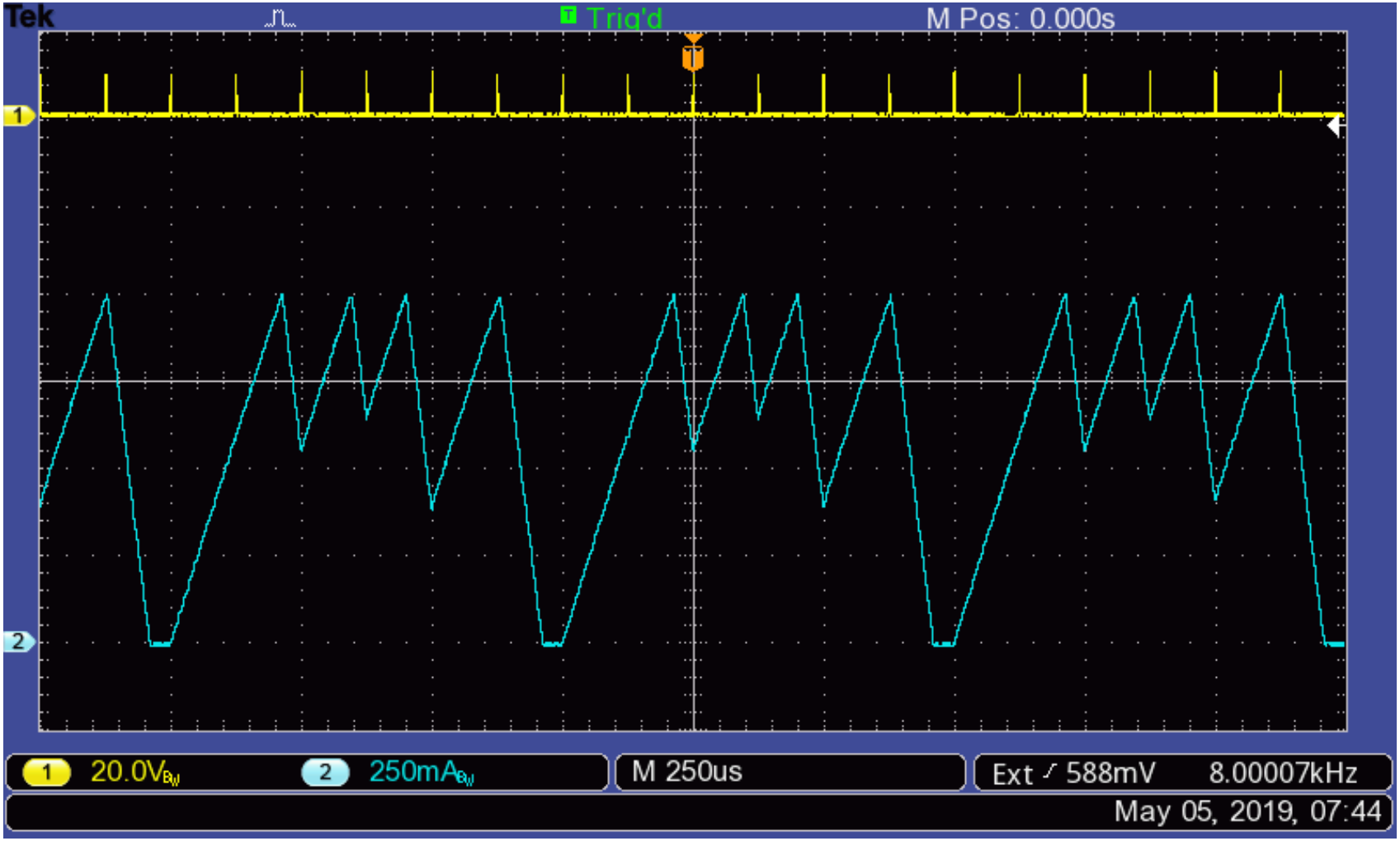
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 998.35\,\mathrm{mA}$$

Period-5 Operation



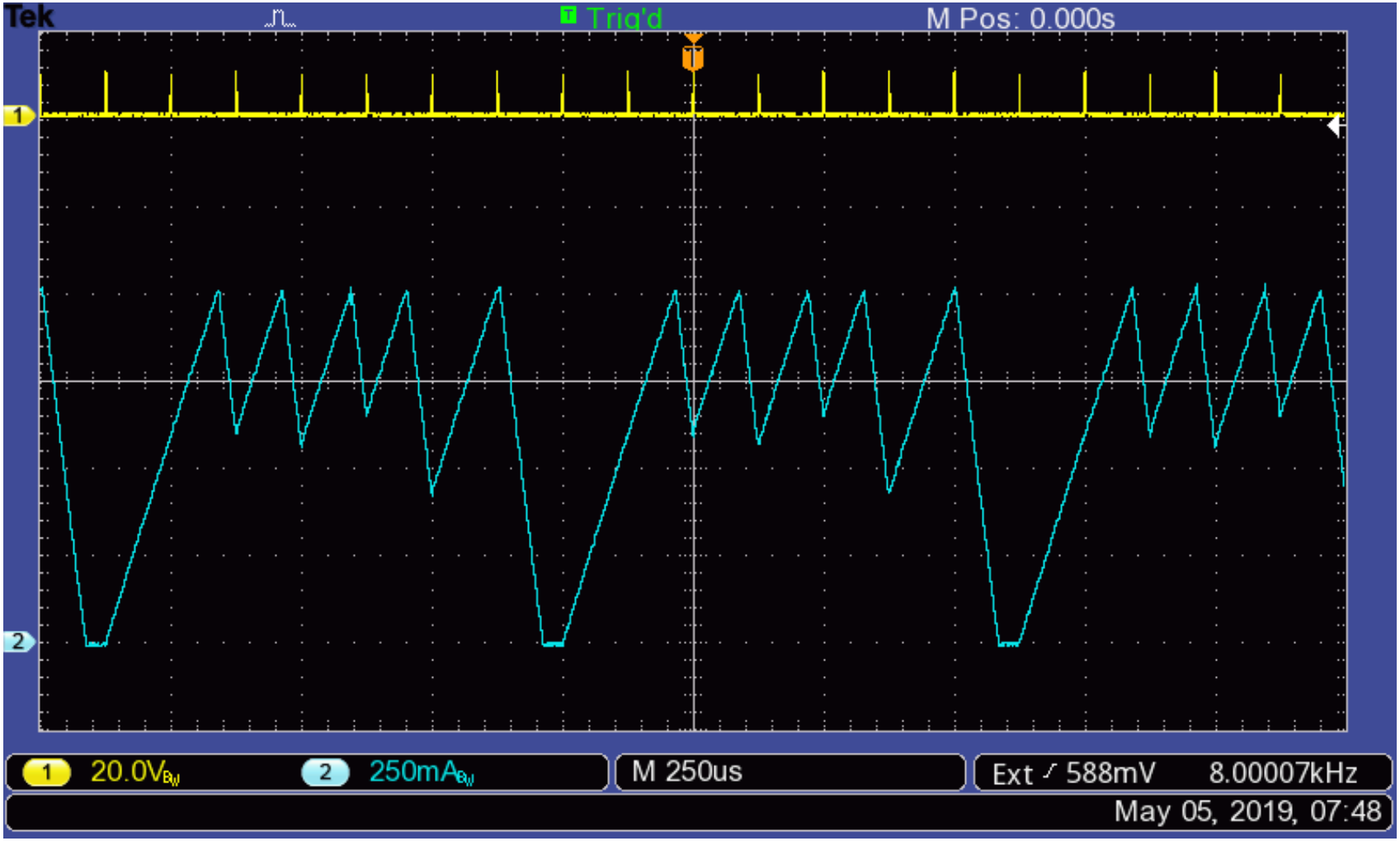
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 975.29\,\mathrm{mA}$$

Period-6 Operation



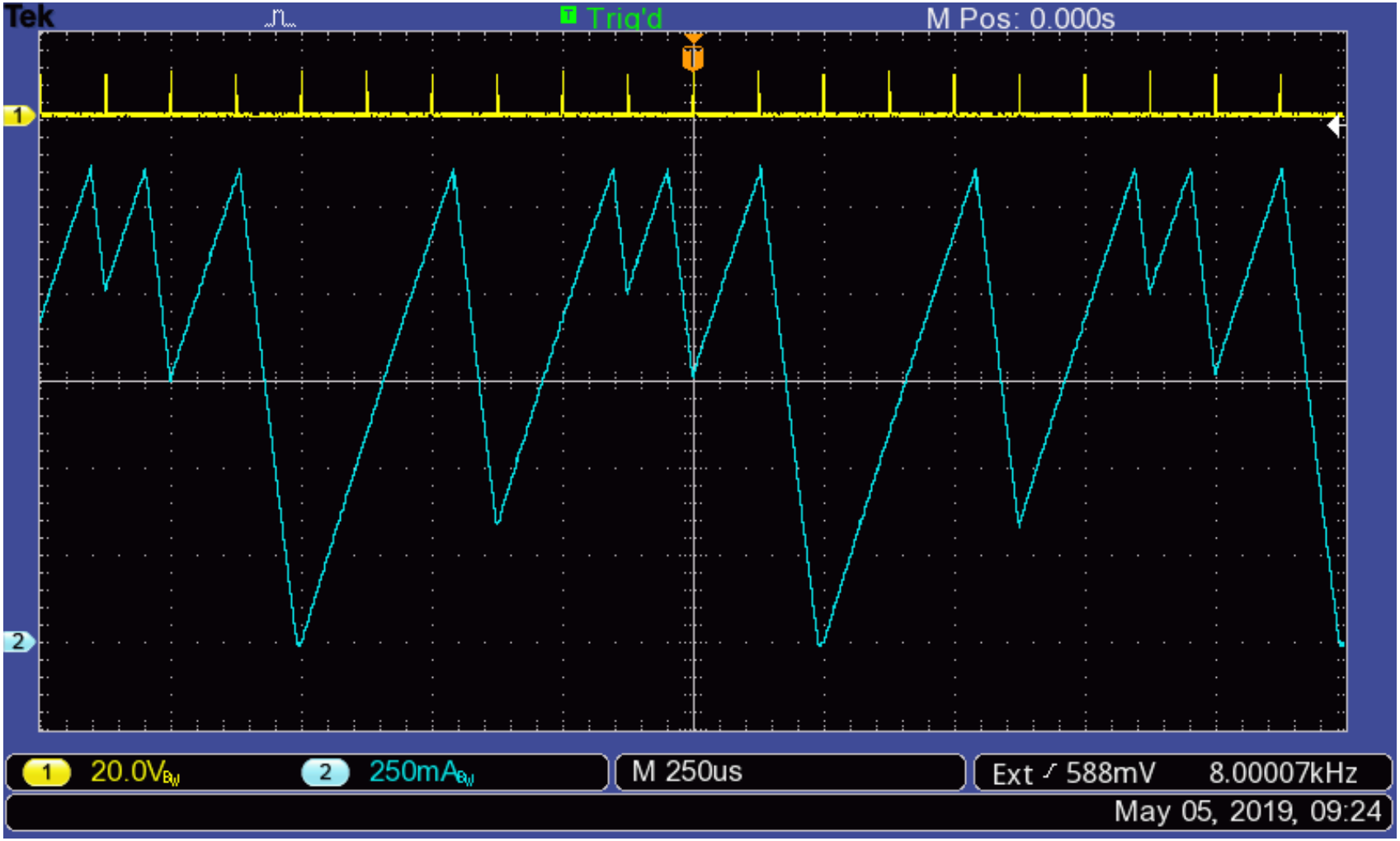
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 1010.36\,\mathrm{mA}$$

Period-7 Operation



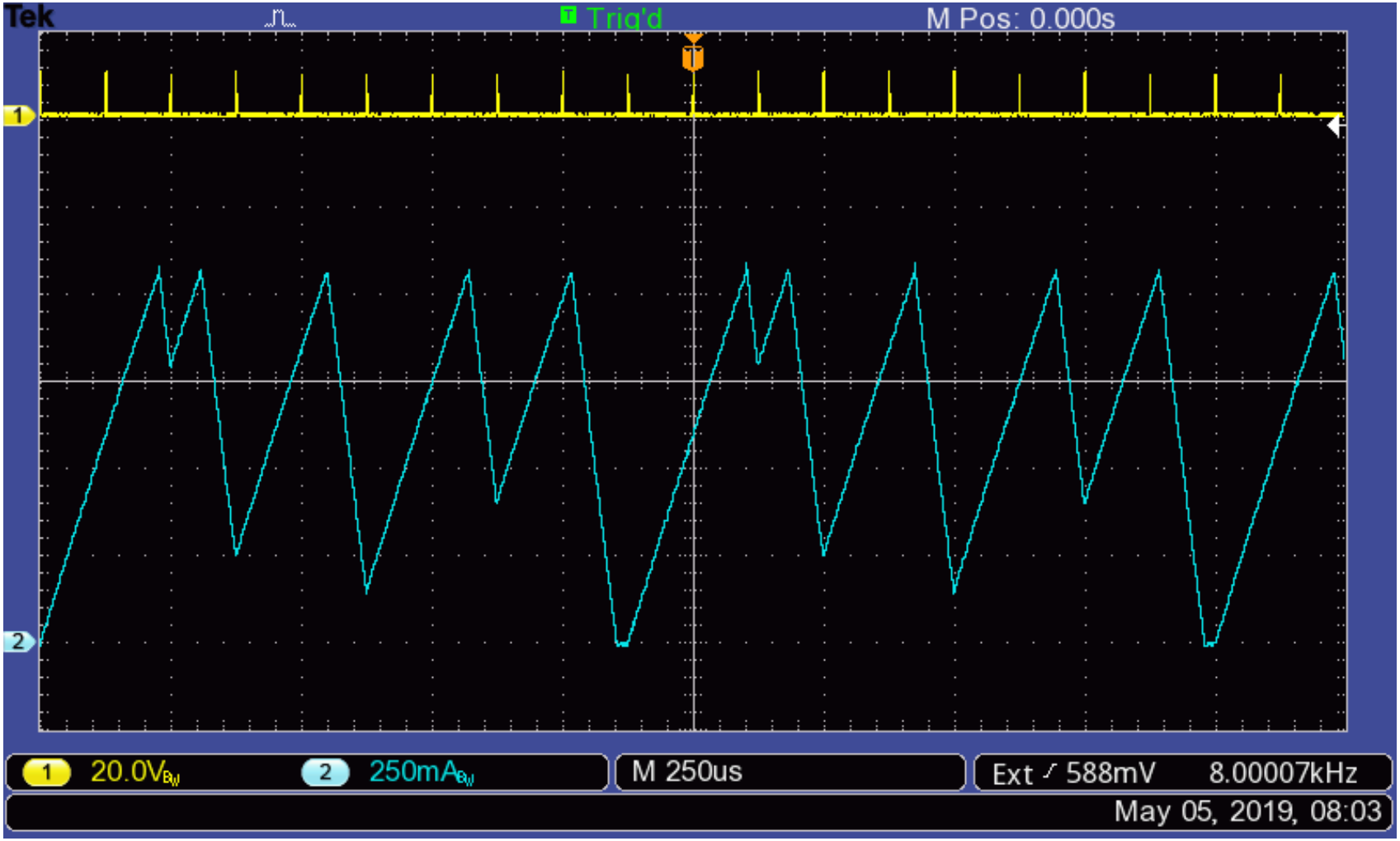
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 1026.21\,\mathrm{mA}$$

Period-8 Operation



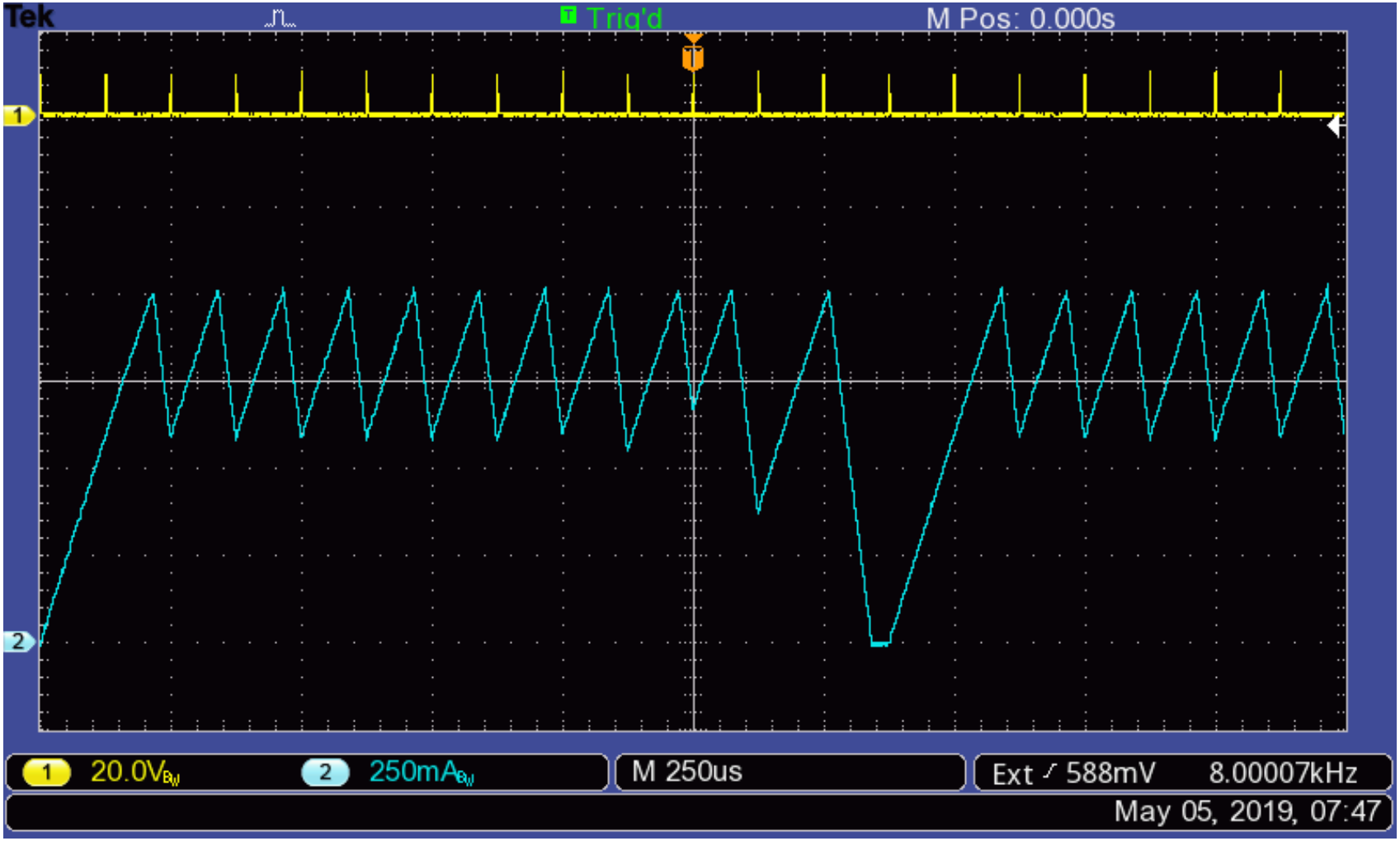
$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 1358.67\,\mathrm{mA}$$

Period-9 Operation



$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 1065.13\,\mathrm{mA}$$

Period-13 Operation



$$V_{IN} = 5\,\mathrm{V},\ V_{OUT} = 17\,\mathrm{V},\ I_m = 1009.40\,\mathrm{mA}$$

Conclusions

- switching cell model of peak limiting current mode control verified
- boost converter switching cell built
- an automated measurement system arranged
- I_{OUT} (I_m) measured for four output voltage values
- good agreement with theoretical predictions!
- higher order discontinuous conduction modes recorded ...
- ... up to 13-th order!
- significantly improved experimental verification
- the theory corresponds to actual processes ...
- **experimental verification successful!**