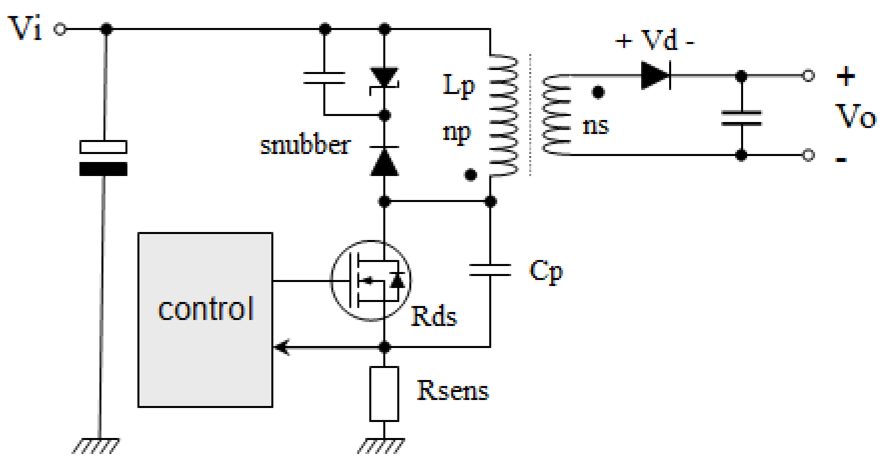
Flyback converter, fixed frequency.

This worksheet is intended to help you in the design of a flyback converter and its transformer. There are two options:

1. Optimal design running always in discontinuous current mode (DCM). This is most often the choice for low power. The transformer inductance will depend on the specifications.
   You select this mode by typing Lp = 0. The worksheet will change Lp to the optimal value and plot it.
2. Run in DCM or CCM with a selected transformer inductance. You may want to run partly in CCM at high power and wide input voltage range. Or you may be using an IC whose current limiter does not allow to always use DCM.
   You select this mode by typing Lp = 'your selected value'.

If you set leak = 0 and turns ratio = 1, you have a buck-boost converter.



Insert your network variables here:

```
minVi = 250             #  [V]    Min. DC input voltage
maxVi = 420             #  [V]    Max. DC input voltage
Vo    = 24              #  [V]    Output voltage
Vd    = 1               #  [V]    Output rectifier diode voltage drop
maxVp = 700             #  [V]    Max. allowed peak voltage over switch
freq  = 67              #  [kHz]  Switching frequency
maxP  = 30              #  [W]    Max. specified output power
leak  = 0.01            #         Ls/Lp (primary leakage/main inductance)
maxB  = 0.306           #  [T]    Max. flux density in ferrite core. Should normally not exceed 0,32T
Afe   = 52    # (EF25)  #  [mm^2] Ferrite core minimum cross section area
Rds   = 2 * 1.8         #  [ohm]  Switch on-resistance (when hot)
Rsens = 1.8             #  [ohm]  Current sense resistor
Cp    = 35e-12          #  [F]    Capacitance parallel to primary winding + fet

nmin  = 5 ; nmax = 10   #         Range of turns ratio in plots: n = np/ns
```

```
Lp    = 0               #  [H]    Transformer primary inductance. ONLY USED IN CCM. Type Lp = 0 to always be in DCM.
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Vi    = 420             #  [V]    Actual DC input voltage
P     = 25              #  [W]    Actual output power    (P must be < or = maxP)
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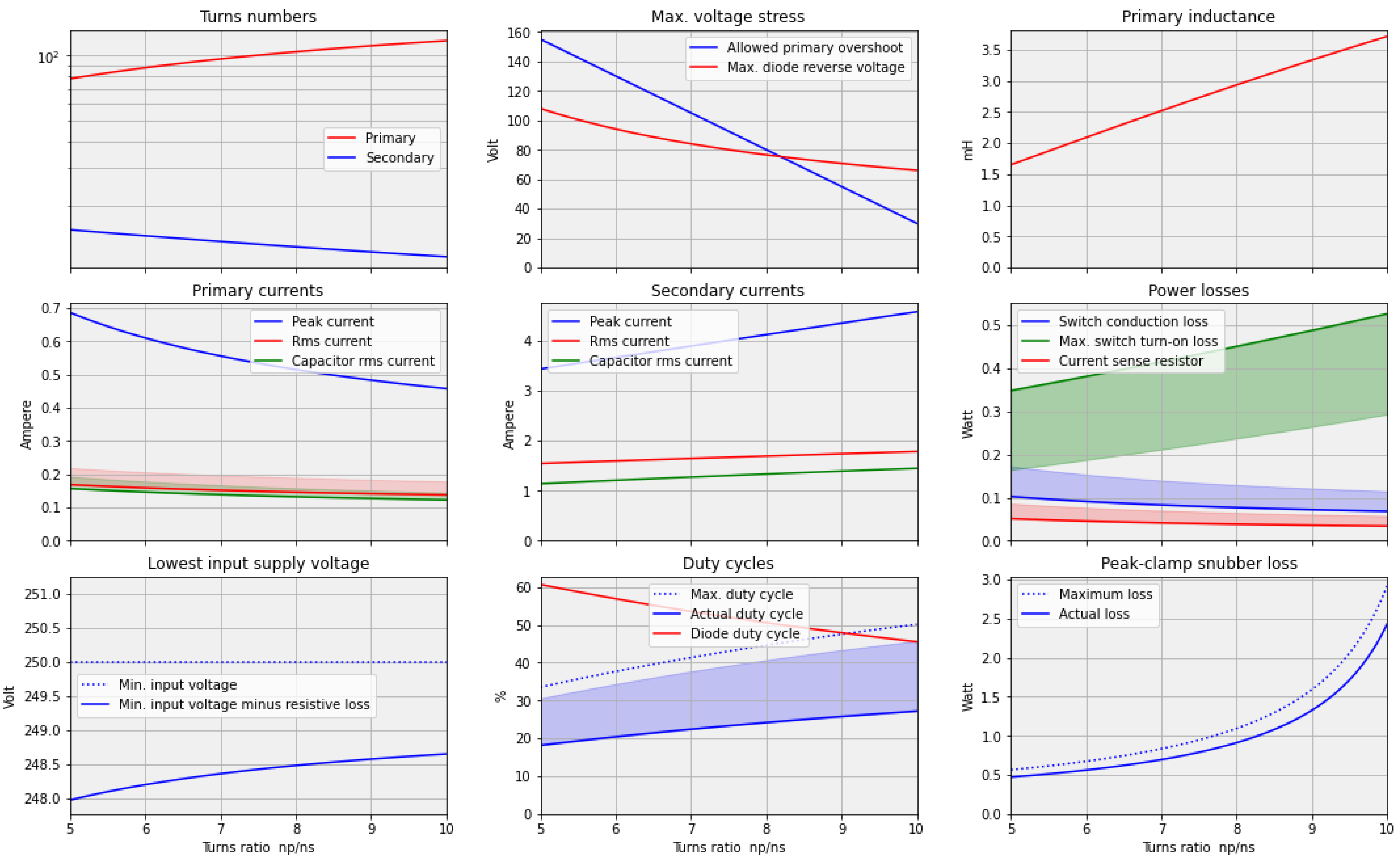

Solid lines in the plots show values with the actual input voltage. Shaded areas show the variation from lowest to highest input voltage at the selected output power.
To see all of the highest component stress from the graphs, choose P = maxP.

A flyback converter can in principle do the job with any turns ratio n from zero to infinity. For practical reasons, however, n has to be restricted to a certain range.
From a survey of the above graphs a suitable turns ratio n = np/ns is chosen and inserted as N below. Also insert the dimensions of a chosen coil former and wire. For a non-circular coil former an equivalent diameter must be used.
The worksheet does not check that you have enough space for your wire. You must verify that yourself.
Now the worksheet calculates the primary and secondary copper resistances and consequently the power loss in them (extra power loss from proximity effects and airgap effects is not included !!) plus a number of other data.
If the number of turns do not become integers or if the core constant AL is inconvenient you can experiment with N and maxB in order to find a better hit.
Finally, by inserting core volume, the core loss and total transformer loss are estimated at max. load for a few selected ferrite types.

Now choose your transformer winding and core data:

```
N         = 8              # Selected turns ratio np/ns
temp      = 100            # Winding temperature       [deg C]
Øprim     = 12             # Primary winding diameter  [mm]
Øsec      = 13             # Secondary winding diameter [mm]
Øprimwire = 0.1            # Primary wire diameter     [mm]
Øsecwire  = 0.4            # Secondary wire diameter   [mm]
parprim   = 1              # Parallel primary wires
parsec    = 1              # Parallel secondary wires
volfe     = 2.99   # (EF25) # Volume of ferrite core    [cm^3]
```

For buck-boost, choose Øprim = Øsec, Øprimwire = Øsecwire, parprim = parsec, and add wire losses manually.

And see results and scope plots for your actual working conditions:

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```
Primary turns number          = 104
Secondary turns number        = 13.0
Primary inductance            = 2.93 mH
Core constant                 = 271 nH/turns^2
Air gap in ferrite centre leg ≈ 0.26 mm             In DCM the air gap is independent on N

Primary wire resistance       = 10.98 ohm
Secondary wire resistance     = 0.093 ohm
Primary wire power loss       = 0.23 W
Secondary wire power loss     = 0.27 W
Conduction loss in switch     = 0.077 W
Current sense resistor loss   = 0.038 W

Peak primary current          = 0.515 A
Input capacitor rms HF current = 0.13 A
Output capacitor rms current  = 1.33 A
Actual duty cycle             = 24 %

Estimated max. core loss 3C90  ≈ 331 mW      Total max. transformer loss ≈ 831 mW
Estimated max. core loss 3C95  ≈ 244 mW      Total max. transformer loss ≈ 745 mW
Estimated max. core loss 3F3   ≈ 351 mW      Total max. transformer loss ≈ 851 mW
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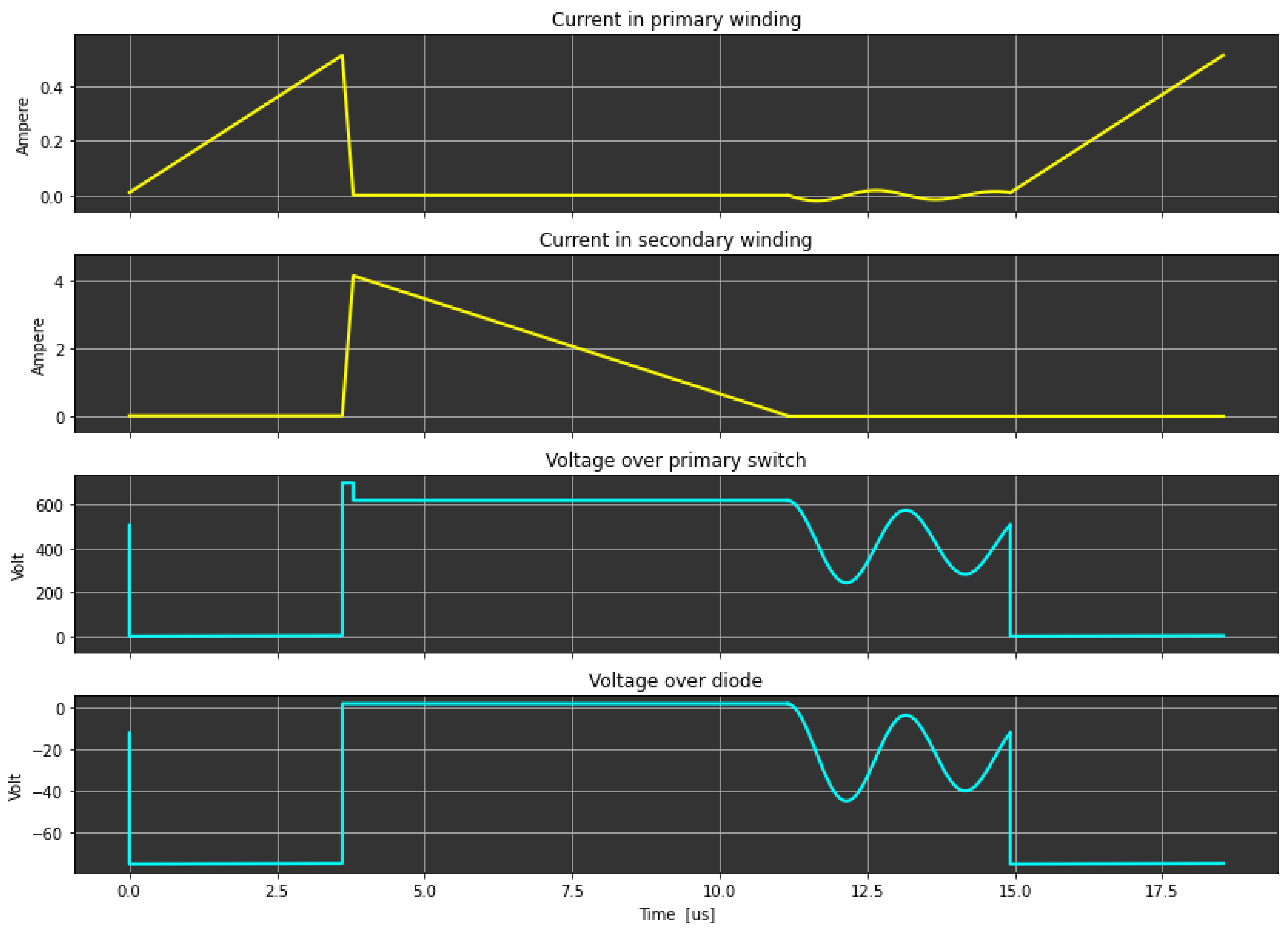
```



The ringing in the inactive time can swing to < 0V over the primary switch, which is true if the switch is completely off.
However, most switches will contain a parallel body diode which will clamp this voltage at zero.

Transformer data summary:

Core: EF25 (E25/13/7)
Winding sequence:
Primary: 104 turns ø 0.1mm in one layer
24V secondary: 13 turns ø 0.4mm triple insulated in one layer
Primary aux: ? turns ø 'whatever' triple insulated in outer layer