How to Use Off-the-Shelf Transformers in Switch Mode Power Supplies

Ali Shirsavar

Biricha Digital Power Ltd

133 Rue Riverview
Rosemere
Quebec – J7A 2K1
Canada

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Understanding Off-the-Shelf Transformers

- Each transformer comes with several windings (usually 6)
  - See Wurth's flex range of transformers
  - https://www.we-online.com/en/components/products/WE-FLEX
- The idea is that the user arranges these windings in either series/parallel or both to get the inductances and turns ratios that they need
  - This way you can get a transformer off-the-shelf at the expense of some performance
- Of course a generic transformer will not perform as well as a custom made one
  - Leakage will not be as good
  - May not have the exact turns ratio/inductance that you need
  - The pin out arrangement may not be ideal

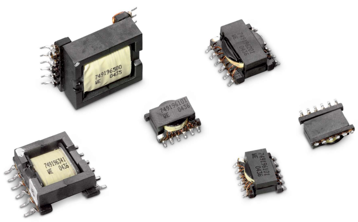

Image taken from: https://www.we-online.com/en/components/products/WE-FLEX

but wouldn't be great to order our transformer along with your other components from your favourite supplier? ....
We think this is possible for low voltage/low power Flyback applications (…convenience at the expense of some performance …)

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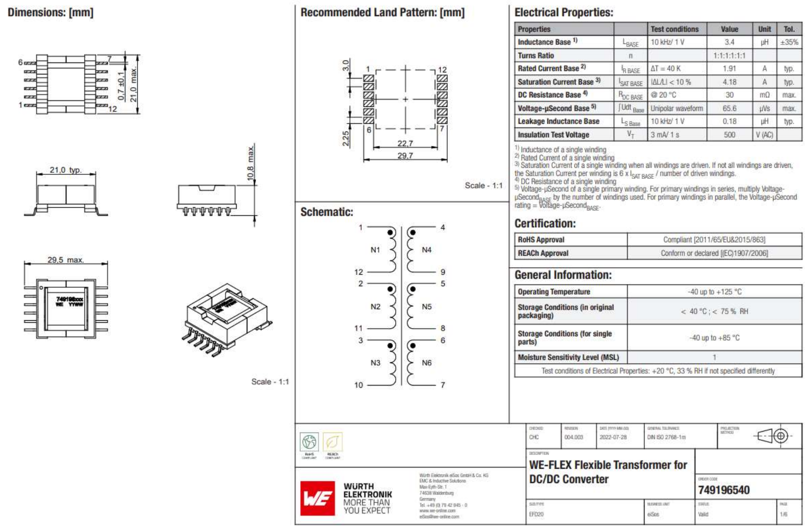
Example Flex Transformer



Dimensions: [mm]

Recommended Land Pattern: [mm]

Schematic:

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance Base 1)	L_{BASE}	10 kHz/ 1 V	3.4	µH	±35%
Turns Ratio	n		1:1:1:1:1:1		
Rated Current Base 2)	$I_{R\ BASE}$	ΔT = 40 K	1.91	A	typ.
Saturation Current Base 3)	$I_{SAT\ BASE}$	|ΔL/L| < 10 %	4.18	A	typ.
DC Resistance Base 4)	$R_{DC\ BASE}$	@ 20 °C	30	mΩ	max.
Voltage-µSecond Base 5)	$\int Udt_{Base}$	Unipolar waveform	65.6	µVs	max.
Leakage Inductance Base	$L_{S\ Base}$	10 kHz/ 1 V	0.18	µH	typ.
Insulation Test Voltage	V_T	3 mA/ 1 s	500	V (AC)	

1) Inductance of a single winding
2) Rated Current of a single winding
3) Saturation Current of a single winding when all windings are driven. If not all windings are driven, the Saturation Current per winding is 6 x $I_{SAT\ BASE}$ / number of driven windings.
4) DC Resistance of a single winding
5) Voltage-µSecond of a single primary winding. For primary windings in series, multiply Voltage-µSecond$_{BASE}$ by the number of windings used. For primary windings in parallel, the Voltage-µSecond rating = Voltage-µSecond$_{BASE}$.

Certification:

RoHS Approval	Compliant [2011/65/EU&2015/863]
REACh Approval	Conform or declared [(EC)1907/2006]

General Information:

Operating Temperature	-40 up to +125 °C
Storage Conditions (in original packaging)	< 40 °C ; < 75 % RH
Storage Conditions (for single parts)	-40 up to +85 °C
Moisture Sensitivity Level (MSL)	1
Test conditions of Electrical Properties: +20 °C, 33 % RH if not specified differently	

CHECKED	REVISION	DATE (YYYY-MM-DD)	GENERAL TOLERANCE
CHC	004.003	2022-07-28	DIN ISO 2768-1m

WE-FLEX Flexible Transformer for DC/DC Converter

ORDER CODE 749196540

SIZE/TYPE	BUSINESS UNIT	STATUS	PAGE
EFD20	eiSos	Valid	1/6

WURTH ELEKTRONIK MORE THAN YOU EXPECT

- As can be seen from the datasheet, this range has 6 windings
- Product family can be found here
  - https://www.we-online.com/en/components/products/pbs/power_magnetics/flexible_transformers_for_smps
- We will soon show how to use these

Datasheet taken from https://www.we-online.com/components/products/datasheet/749196540.pdf

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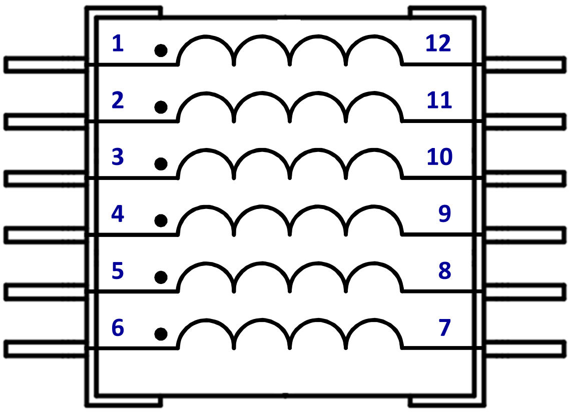
Example Wurth Flex Transformer EFD15 & 20 Range*



- Given this set up we can wire up our transformer to have a fixed set of turns ratios (N)

* Pinout for other sizes for other transformers may vary but the principle stays the same

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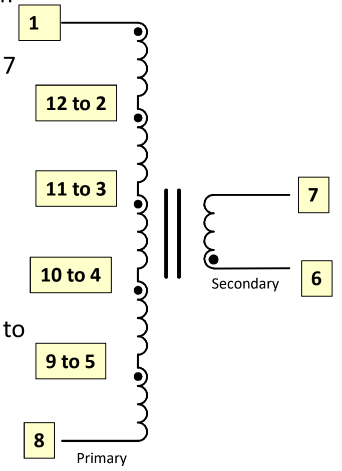
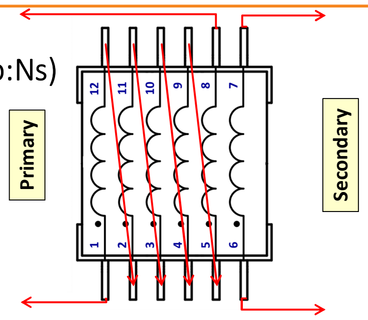
Wurth EFD20/15 Flex Transformer Example Turns Ratio (N = Np:Ns)

- We have 6 coils and we can connect them any which way that we like
- If I use the coil connected between pins 7 and 6 as my secondary
- And connect pin 9 to 5, 10 to 4, 10 to 3 and 12 to 2
- Then 8 and 1 will be my primary
- And I will have a Np/Ns → N of 5:1
  - Np = Primary turns, Ns = Secondary turns
- Of course there are many ways of wiring to get the same N, however, we have used the current convention just for simplicity
  - This gives a clean layout at the expense of more leakage
  - If we interleave then we will have lower leakage but slightly messier layout





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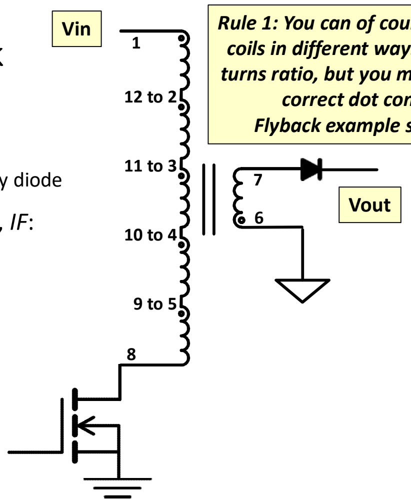
EFD20/15 Flex Transformer Example Flyback

- All we have to do now to get a DC-DC Flyback is to connect:
  - Pin 1 to Vin, Pin 8 to Drain of our switch
  - Pin 6 to secondary Ground and Pin 7 to the anode of the secondary diode
- Our choice is limited so we can use off-the-shelf transformer, *IF*:
  - We can get the right turns ratio (N)
  - We can get the right inductance
  - We can stay within the available Rated Current limit (RMS)
  - We can stay under our Saturation Current limit (Peak)
- Desired N and inductance can be easily calculated
  - from REDEXPERT or Biricha-WDS
- Actual N, inductance, rated and saturation currents can be
  - Easily read off Biricha Flex Transformer spreadsheet
  - Calculated from the device datasheet
- Biricha Flex Transformer Spreadsheet lists all of the above parameters for all the suitable turns ratios in Flyback applications
- We must follow just 5 rules to we select and connect up our transformer



Rule 1: You can of course connect the coils in different ways for the same turns ratio, but you must stick to the correct dot convention
Flyback example shown here

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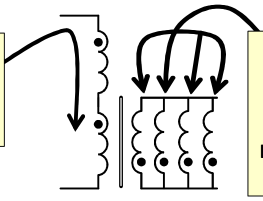
Rated Current as Our Winding Arrangement Changes

- The datasheet* specifies the rated current for just 1 coil out of 6
- They call this Rated Current Base or IR BASE (IR_Base) in RMS
  - EDF20 part datasheet shown earlier (Part No 74919654) has a IR_Base of 1.91A
  - Rated current is a thermal characteristic i.e. each one of the 6 coils can have 1.91A(RMS) without dissipating too much heat
  - e.g. if our secondary has 4 parallel paths all the way, then our overall rated current will be 4 x the specified IR_Base → 1.91 x 4 = 7.64A
- Note that paralleled windings on the *same core* are not separate inductances; they are just one inductance with more copper; just like having thicker wire → Rule 2: *when you parallel coils, the inductance stays the same*

Electrical Properties:

Properties		Value	Unit
Inductance Base 1)	L_{BASE}	3.4	µH
Turns Ratio	n	1:1:1:1:1:1	
Rated Current Base 2)	$I_{R\ BASE}$	1.91	A
Saturation Current Base 3)	$I_{SAT\ BASE}$	4.18	A
DC Resistance Base 4)	$R_{DC\ BASE}$	30	mΩ
Voltage-µSecond Base 5)	$\int Udt_{Base}$	65.6	µVs
Leakage Inductance Base	$L_{S\ Base}$	0.18	µH
Insulation Test Voltage	V_T	500	V (AC)

Example 1: Lowest number of current paths for primary is 1 ∴ Primary Rate Current IR_Pri = IR_Base = 1.91A



Lowest number of current paths for secondary is 4 current ∴ Secondary Rated Current IR_Sec = 4 x IR_Base = 1.91 x 4 = 7.64A

Datasheet data taken from https://www.we-online.com/components/products/datasheet/749196540.pdf

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Rated Current as Our Winding Arrangement Changes

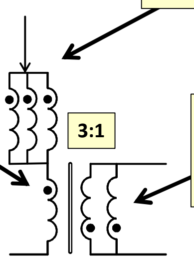
- Important: we must always use the lowest number of current paths in our primary or secondary for our calculations
- In other words if we have 3 coils in parallel but in series with the a single coil then our rated current is limited by that single coil
  - This is because IR_Base is a thermal characteristic of the device and that single coil will get hot

Rule 2: when you parallel coils on an off-the-shelf transformer, the inductance stays the same

Although there are 3 coils in parallel here, our primary rated current IR_Pri is still only 1 x IR_Base

Because the bottleneck is here, where we only have one single current path

This single path will get hot if we pass more than IR_Base through it!



The secondary on the other hand has a rates current IR_Sec of 2 x IR_Base because we have 2 parallel paths for the current

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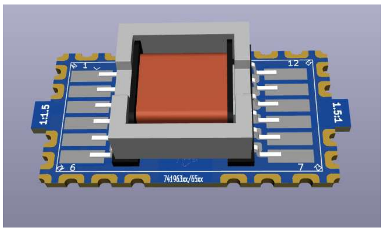
All the Turns Ratios that We Can Have!

- As mentioned earlier, the 6 coils can be connected in many different ways to get the same turns ratio
  - And of course the pin numbers may vary depending on the transformer that you use → always consult device datasheet
- However, there are only a few options that are applicable/useable for a low voltage/low power DC-DC Flyback
- We have 6 coils, for our DC-DC Flybacks, we can have a total of 9 combinations :
  - 5:1, 4:1, 3:1, 3:2 (1.5:1),
  - 2:1 → 2 useful winding arrangements/versions (more in this later)
  - 1:1 → 3 useful winding arrangements/versions (more on this later)
- Of course, if we turn our transformer around we will also have:
  - 1:5, 1:4, 1:3, 2:3, 1:2
  - Often needed for step up applications



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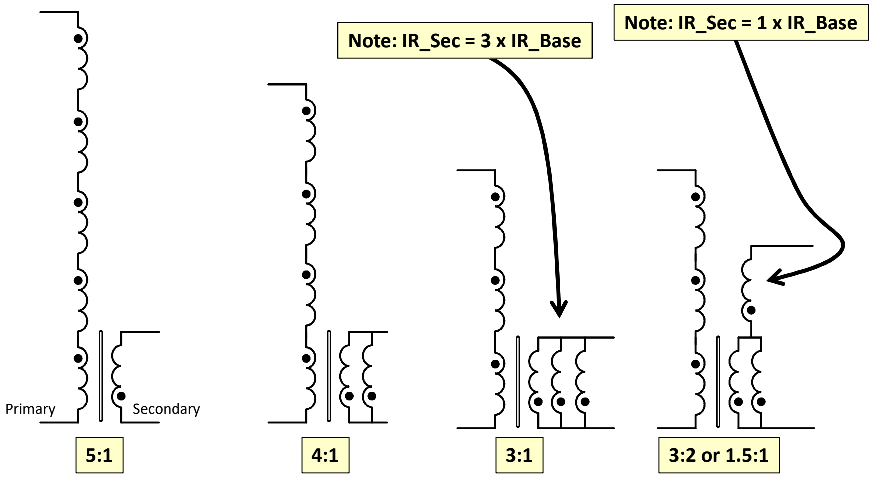
All the Turns Ratios that We Can Have

- To reduce confusion, let us go through *ALL* the combinations
  - But we just need to follow a handful of simples rules

- Rule 1: Pinout will vary depending on the device and your layout, but the dot convention MUST stay the same
- Rule 2: When you parallel coils, the inductance stays the same but rated current increases

Rule 3: Do not leave coils unconnected as it will increase your losses



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What is the Best Way to Parallel the Coils?

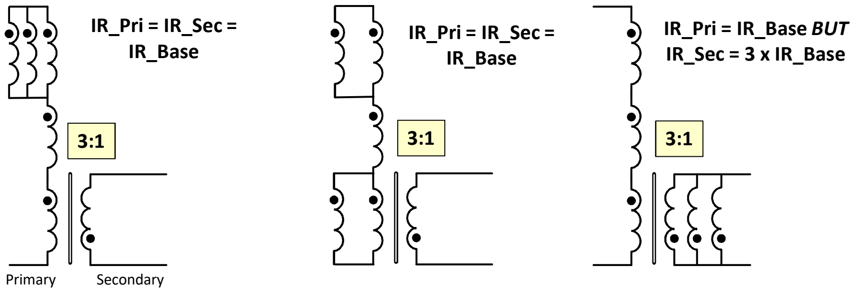
- We 6 coils; we can't have any coils unconnected (Rule 3) but which set up gives us the highest rated primary current IR_Pri and highest rated secondary current IR_Sec?

Reminder:

Rule 1: Stick to the dot convention

Rule 2: For paralleled coils the inductance stays the same but the rated current increases

Rule 3: We can not leave any coils unconnected



Rule 4: Parallel the coils such that you maximise the number of current paths in either primary or secondary

For step down applications, we normally would like to maximize the current in the secondary

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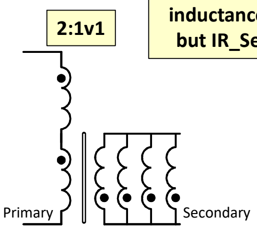
Back to All the Turns Ratios that We Can Have

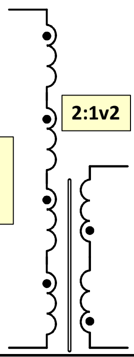
- We have looked at 5:1, 4:1, 3:1, 3:2, so let us now look at 2:1
  - We can have more than 1 useful version of 2:1
- For 2:1v1
  - Primary Rated Current = IR_Base i.e. 1.92A from the datasheet
  - Secondary Rated Current = IR_Base x 4 = 1.92x4 = 7.68A
- For 2:1v2
  - Primary Rated Current IR_Pri = IR_Base i.e. 1.92A (datasheet)
  - Secondary Rated Current IR_Sec = IR_Base x 1 = 1.92A

We will explain how to calculate inductances shortly but first let us look at our last remaining turns ratio → 1:1

2:1v1 has a smaller primary inductance LPri than 2:1v2 but IR_Sec = 4 x IR_Base

2:1v2 has a MUCH larger primary inductance LPri IR_Sec is only 1 x IR_Base





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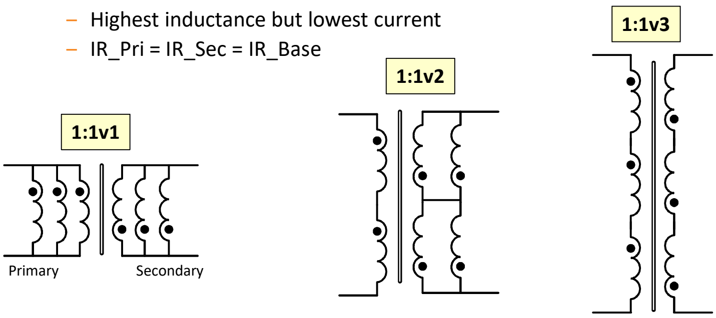
Finally 1:1

- For 1:1v1
  - Smallest inductance (compared to the other version) but biggest IR_Pri & IR_Sec
  - IR_Pri = IR_Sec = 3 x IR_Base
- For 1:1v2
  - Medium Inductance, medium IR_Pri & IR_Sec
  - IR_Pri = IR_Base, IR_Sec = 2 x IR_Base
- For 1:1v3
  - Highest inductance but lowest current
  - IR_Pri = IR_Sec = IR_Base

Primary and secondary inductances of 1:1v3 are 9 times bigger than those of 1:1v1

But how does putting coils in series on the same core impact their inductance?

We will talk about that next



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How Do We Calculate our Primary and Secondary Inductances?

- The datasheet specifies the inductance of one coil LBASE
  - In this case LBASE is 3.4uH → this means we have 6 identical 3.4uH coils wound on the same core
  - We already know that if we parallel these coils the inductance stays the same but the rated current increases
- But what if we put them in series to get different turns ratios?
- We know from school level physics that the inductance of a coil L is proportional to the "square of the number of turns":

$$L = k \times (n)^2 \rightarrow = \text{LBASE}$$

  - Where n is the number of turns for ONE coil
  - and everything else in our case is constant (because we have fixed them)
- So if we connect 2 coils in series we double the number of turns and our inductance goes up by a factor of 4 (i.e. 2^2) and if we connect 3 in series our inductance goes up by a factor of 9 (i.e. 3^2) and so on ….

Electrical Properties:

Properties		Value	Unit
Inductance Base 1)	L_{BASE}	3.4	µH
Turns Ratio	n	1:1:1:1:1:1	
Rated Current Base 2)	$I_{R\ BASE}$	1.91	A
Saturation Current Base 3)	$I_{SAT\ BASE}$	4.18	A
DC Resistance Base 4)	$R_{DC\ BASE}$	30	mΩ
Voltage-µSecond Base 5)	$\int Udt_{Base}$	65.6	µVs
Leakage Inductance Base	$L_{S\ Base}$	0.18	µH
Insulation Test Voltage	V_T	500	V (AC)

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How Do We Calculate our Primary and Secondary Inductances?

- From previous slides we know that our total inductance for either primary or secondary is given by $\boldsymbol{L} = \boldsymbol{k} \times (\boldsymbol{n})^{2}$
- We also know that the inductance for 1 coil is given in the datasheet as ∴ LBASE = $\boldsymbol{k} \times (\boldsymbol{n})^{2}$
  - In our case = 3.4uH
- If we connect 2 coils in series we double the number of turns and our inductance becomes $\boldsymbol{L} = \boldsymbol{k} \times (2\boldsymbol{n})^{2}$ or $\boldsymbol{L} = \boldsymbol{k} \times (\boldsymbol{n})^{2} \times 2^{2}$
  - Or LBASE x 2^2 → in our case 3.4uH x 4 = 13.6uH
- If we connect 3 in series we triple n → $(3n)^2$
  - Or LBASE x 3^2 → in our case 3.4uH x 9 =30.6uH

Rule 5: Total inductance is given by:
Lpri = LBASE x (Number of primary coils connected in series)^2
Lsec = LBASE x (Number of secondary coils connected in series)^2

Electrical Properties:

Properties		Value	Unit
Inductance Base 1)	L_{BASE}	3.4	µH
Turns Ratio	n	1:1:1:1:1:1	
Rated Current Base 2)	$I_{R\ BASE}$	1.91	A
Saturation Current Base 3)	$I_{SAT\ BASE}$	4.18	A
DC Resistance Base 4)	$R_{DC\ BASE}$	30	mΩ
Voltage-µSecond Base 5)	$\int Udt_{Base}$	65.6	µVs
Leakage Inductance Base	$L_{S\ Base}$	0.18	µH
Insulation Test Voltage	V_T	500	V (AC)

* L is the inductance of a l long solenoid , N is the number of turns, μo is the permeability free space A is the and l is the length

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All Data We Need for EVERYTHING in One Spreadsheet

Np	NS	Np/Ns	Primary Coils in Series	Primary Coils in Parallel	Lowest No of Current Paths on Primary	Secondary Coils in Series	Secondary Coils in Parallel	Lowest No of Current Paths on Secondary
5	1	5	5	1	1	1	1	1

Order Code	Datasheet	Lpri (µH)	IR Pri (A)	Primary ISAT (A)	IR Sec (A)	Lsec (µH)	VT (V (AC))	Size
74919734	SPEC	5 2.5	3 20	3.90	3 20	3.70	500	ETD39
74919733	SPEC	85.0	.20	1.98	20	39.40		
749197321	SPEC	932.5	3.20	0.82	.20	77.30		
749197311	SPEC	3212.5	3.20	0.38	3.20	128.5		
749197241	SPEC	550.00	2.50	3.49	2.50	22.00		
749197231	SPEC	902.50	2.50	1.90	2.50	36.10		
749197221	SPEC	1735.00	2.50	0.80	2.50	69.40		
749197211	SPEC	2845.00	2.50	0.40	2.50	[illegible]		
749196547	SPEC	85.00	2.30	4.72	2.30	3.40		
749196537	SPEC	107.50	2.30	3.89	2.30	4.30		
749196527	SPEC	132.50	2.30	3.37	2.30	5.30		
749196517	SPEC	247.50	2.30	1.62	2.30	9.90		
749197141	SPEC	375.00	2.20	3.72	2.20	15.00		
749197131	SPEC	607.50	2.20	2.20	2.20	24.30		
749197121	SPEC	1157.50	2.20	1.00	2.20	46.30		
749197111	SPEC	1877.50	2.20	0.48	2.20	75.10		
749196540	SPEC	85.00	1.91	5.02	1.91	3.40		
749196530	SPEC	107.50	1.91	3.49	1.91	4.30		
749196520	SPEC	132.50	1.91	3.04	1.91	5.30		
749196510	SPEC	247.50	1.91	1.40	1.91	9.90		
749196541	SPEC	190.00	1.70	2.95	1.70	7.60		
749196531	SPEC	242.50	1.70	2.64	1.70	9.70		
74919652	SPEC	300.00	1.70	2.08	.70	12.00		
74919651	SPEC	57.50	1.70	0.59	.70	22.30		
749196 8	SPEC	90.00	1.35	3.58	35	7.60		
49196 38	SPEC	2 2.5	35	2.6	1 35	9.70		

Data | Np/Ns = 5:1 | Np/Ns = 4:1 | Np/Ns = 3:1 | Np/Ns = 3:2 (1.5:1) | Np/Ns = 2:1v1 | Np/Ns

So far we have given all the equations and explained exactly where they come from but we recommend using our Flex Transformer Spreadsheet

The final parameter that we need for Flyback design is Primary Saturation Current

For completeness we will explain this in detail also

…

But we still recommend using the spreadsheet! ☺

These rules are becoming cumbersome so let us put everything that we need for every combination in just one spreadsheet

Please download Biricha's Flex Transformer Spreadsheet from: www.biricha.com/flex

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How Do We Calculate Our Primary Saturation Current?

- The datasheet specifies our Saturation Base Current ISAT_BASE
  - In this cause it is 4.18A *PEAK* not RMS!)
- Unlike "Rated Current" which is a thermal parameter, "Saturation Current" is determined by the maximum flux that our core can handle
  - Saturation current is determined by our PEAK current and not RMS
  - If we saturate our core, it stops acting like an inductor and things will go very wrong!
  - It's a little bit like a washing up sponge that is completely saturated with water → it stops acting like a sponge and water will go everywhere!
- Remember from school physics that our flux is proportional to our Amp-turns*
  - If our core saturates with 100A and only 1 turn, we can also saturate with 1A and 100 turns
- We can consider** ISAT_BASE as the current that will saturate our core when we have the maximum number of turns, i.e. when all 6 coils are connected in series
  - But if we only use 3 coils in series and nothing else, then we have halved our number of turns, therefore we can have twice as much current before saturation

Properties		Value	Unit
Inductance Base [1)]	L_{BASE}	3.4	µH
Turns Ratio	n	1:1:1:1:1:1	
Rated Current Base [2)]	$I_{R\ BASE}$	1.91	A
Saturation Current Base [3)]	$I_{SAT\ BASE}$	4.18	A
DC Resistance Base [4)]	$R_{DC\ BASE}$	30	mΩ
Voltage-µSecond Base [5)]	$\int Udt_{Base}$	65.6	µVs
Leakage Inductance Base	$L_{S\ Base}$	0.18	µH
Insulation Test Voltage	V_T	500	V (AC)

Yes it is be bit confusing → let us elaborate with an example in the next slide

* Flux ϕ (in Webers) = Magneto-motive Force (MMF in A.turns) / Reluctance (A/Weber)
** this is for ease of explanation only, in practice it is measured a different way, please consult the datasheet

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How Do We Calculate Our Primary Saturation Current?

- First, please remember that in a Flyback transformer* when the current in the primary winding is flowing, there is no current flowing in the secondary "winding"
  - There is no net contribution to the Amp-Turns from the secondary and therefore, we only need to consider the primary currents and coils for saturation purposes
- From previous slides we know that paralleled coils on the same core do not increase our number of turns → it is just like using thicker wire
  - We ignore all parallel coils and only consider series coils in our primary
- If we use all 6 coils (in series on the primary), we can have our maximum number of turns and therefore minimum saturation current
  - Primary Saturation Current, ISAT_PRI = ISAT_BASE
- If we have 5 coils in series on the primary the we have only used 5/6th of our maximum number of turns, therefore we can increase our ISAT_PRI by 6/5 … and so on
  - Primary Saturation Current ISAT_PRI = 5/6 x ISAT_BASE = 1.2 x ISAT_BASE
  - e.g. if ISAT_BASE in datasheet = 4.18A, then ISAT_PRI = 1.2 x 4.18A = 5.0A
- And so on …

Rule 6: For Flyback transformers

ISAT_Pri =
6 x ISAT_BASE / Primary coils in series
…
But please use the spreadsheet! ☺

* Ideal conditions, ignoring any cross conduction and turn on/off times

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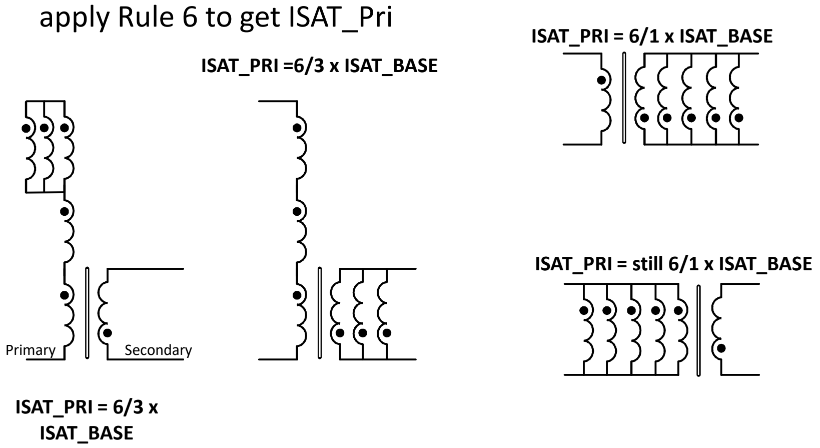
How Do We Calculate Our Primary Saturation Current

- Only count series connected coils on the primary and then apply Rule 6 to get ISAT_Pri



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Summary of Rules

- So far have given
  - Full explanation +
  - All necessary equations and where they come from +
  - Flex Transformer Spreadsheet containing most of the useful combinations of turns ratios and coils + connections
  - 6 simple rules to follow …
- The Rules
  - Rule 1: Stick to the dot convention
  - Rule 2: When we connect coils in parallel on the same core the inductance stays the same and the rated current increases
  - Rule 3: We can not leave any coils unconnected
  - Rule 4: Parallel the coils such that you maximum the number of current paths in either primary or secondary
  - Rule 5: Total inductance is given by:
    - Lpri = LBASE x (Number of primary coils connected in series)^2
    - Lsec = LBASE x (Number of secondary coils connected in series)^2
  - Rule 6: For Flyback transformers
    - ISAT_Pri = 6 x ISAT_BASE / Primary coils in series

Let us now look at a few design examples
We will use Biricha WDS and Flex Transformer Spreadsheet to do all our calculations

You can download everything for free from www.biricha.com/omicron & www.biricha.com/flex

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Design Examples and Calculations with WDS and Flex Transformer Spreadsheet

- Biricha WDS Automatic Power Supply Design Software that allows you to design and stabilise power supply control loops down lot component level
  - Detailed control loop design is covered in our Analog Power Supply Design Workshop, for now we will just use WDS
- It calculates all necessary voltages, currents and stresses on power devices
  - So you can select your power components
- It calculates the size of our output capacitor based on our ripple and step response requirements
- Finally it provides us with IR_Pri, IR_Sec, ISAT_Pri, Turns Ratio, Transformer Primary and Secondary Inductances (Lpri and Lsec respectively)
  - In other words *ALL* the parameters that we need to select our off the shelf transformer
- We can then use our Flex Transformer spreadsheet to see if we can find a suitable of-the-shelf component (or calculate by hand using the techniques shown in this presentation)
  - If you can't find one then you have to get a custom transformer

You can download WDS and our Flex Transformer spreadsheet for free from www.biricha.com/omicron & www.biricha.com/flex

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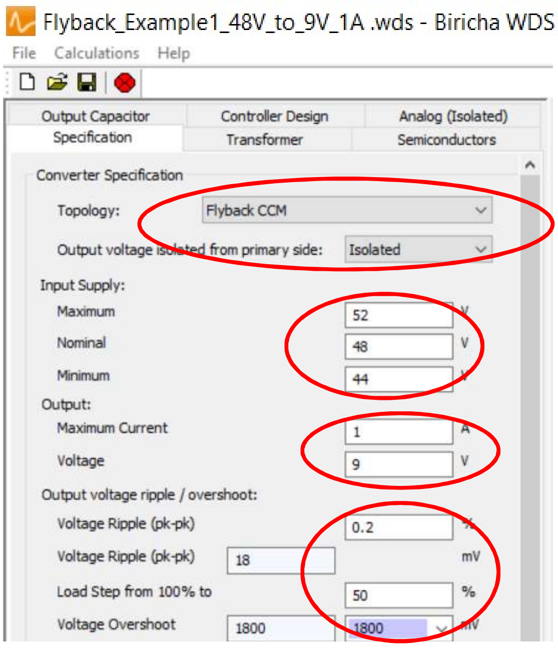
Example 1

Step 1 : In the Specification tab, fill in your Vin, Vout and Iout

Followed by acceptable ripple on the output and how fast you want your power supply to recover after a 50% step change in load → this determines the size of the output cap

Leave everything else as default for now



- 48V in - Isolated 9V,1A out
- Fs = 200kHz but we may have to tweak a little bit to be able to buy an off-the-shelf transformer
- WDS to automatically calculate all values needed for silicon, control loop, output caps and transformer

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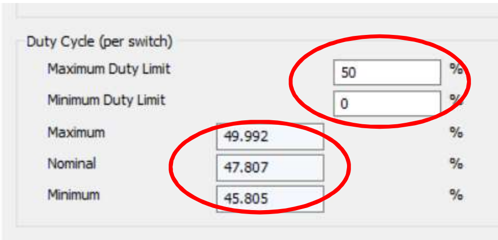
Example 1 – Isolated Flyback 48V In – 9V@1A Out

- WDS calculates our turns ratio based our maximum duty cycle
- Flyback topology is quite forgiving with regard to the maximum duty cycle
  - Therefore we can iteratively adjust this until you get a turns ratio that is available in our of-the-shelf transformers
- Max Duty can be set to anything between 30 to 55% and still get reasonable results
  - Let us start with 50% but if necessary we can change this to get near to our available turns ratios
  - Please remember that we can only have 5:1, 4:1, 3:1, 3:2 (1.5:1), 2:1 (2 versions) and 1:1 (3 versions)

Step 2: For now set the Max duty limit to 50%

We will then iterate and adjust this to find a available off-the-shelf transformer



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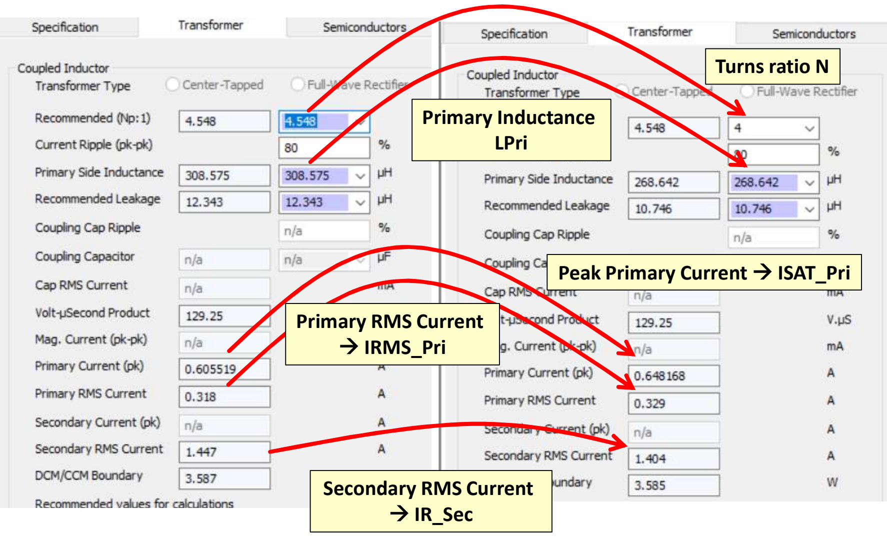
Example 1 – Isolated Flyback 48V in – 9V@1A Out

- As we play with our turns ratio; WDS then will recalculate EVERYTHING else that you need to select your transformer



Step 3: Iterate reasonable turns ratios and then use WDS values to find the correct transformer from the Spreadsheet

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Example 1 – Isolated Flyback 48V in – 9V@1A Out

Order Code	Datasheet	Lpri (µH)	IR Pri (A)	Primary ISAT (A)	IR Sec (A)	Lsec (µH)	VT (V (AC))	Size
749196248	SPEC	105.60	0.80	2.40	1.60	6.60	1500	ER14.5/6
749196238	SPEC	132.80	0.80	1.95	1.60	8.30	1500	ER14.5/6
749196228	SPEC	185.60	0.80	1.41	1.60	11[illegible]	[illegible]	[illegible]
749196218	SPEC	345.60	0.80	0.72	1.60	21[illegible]	[illegible]	[illegible]
749196141	SPEC	136.00	0.55	1.44	1.10	8.[illegible]	[illegible]	[illegible]
[illegible]	SPEC	174.40	0.55	1.10	1.10	10.90	500	ER11/5
[illegible]	SPEC	235.20	0.55	0.81	1.10	14.70	500	ER11/5
[illegible]	SPEC	438.40	0.55	0.33	1.10	27.40	500	ER11/5
749196148	SPEC	136.00	0.50	1.53	1.00	8.50	1500	ER11/5
749196138	SPEC	174.40	0.50	1.20	1.00	10.90	1500	ER11/5
749196128	SPEC	235.20	0.50	0.83	1.00	14.70	1500	ER11/5
749196118	SPEC	438.40	0.50	0.44	1.00	27.40	1500	ER11/5

\+ ≡ Np/Ns = User_Defined ▾ Np/Ns = 5:1 ▾ Np/Ns = 4:1 ▾ Np/Ns =

Click on SPEC for datasheet

We have found our part ☺ Our transformer selection is complete!

- Look for WDS values in this order:
  - N → 4:1
  - IR_Pri >= 0.329A
  - Lpri >= 268.642uH
  - IR_Sec >= 1.404A
  - ISAT_Pri >= 0.329A

Step 4: Use WDS calculated data to quickly find a suitable transformer If you do not find a suitable transformer, try 3:1 or 5:1 or change what ever else you can change

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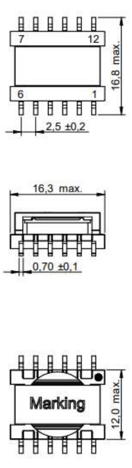
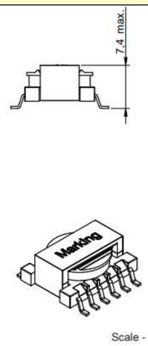
WE 749196218 Transformer Datasheet*

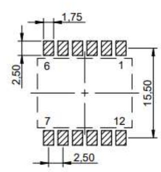
Dimensions: [mm]



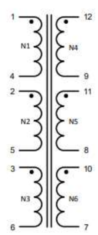
Of course we have everything in the Flex Transformer spreadsheet, but using the material in this presentation we can also calculate by hand



Recommended Land Pattern: [mm]

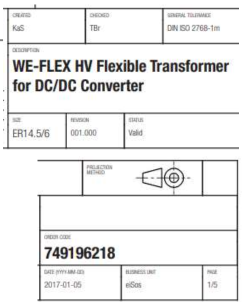


Schematic:



Electrical Properties:

Properties	Test conditions		Value	Unit	Tol.
Inductance Base	100 kHz/ 100 mV	L_{BASE}	21.6	µH	±20%
Turns Ratio		n	1:1:1:1:1:1		
Voltage-µSecond Base		$\int Udt_{Base}$	63.4	µVs	max.
Rated Current Base	ΔT = 40 K	$I_{R\ BASE}$	0.8	A	typ.
Saturation Current Base	|ΔL/L| < 10 %	$I_{SAT\ BASE}$	0.48	A	typ.
DC Resistance Base	@ 20 °C	$R_{DC\ BASE}$	200	mΩ	max.
Leakage Inductance Base	100 kHz/ 1 V	$L_{S\ BASE}$	0.17	µH	typ.
Insulation Test Voltage	all windings	U_T	1500	V (AC)	



* Full datasheet on: https://www.we-online.com/components/products/datasheet/749196218.pdf

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Calculations by Hand – For Completeness Only!

- Primary has 4 coils in series and only 1 current path
  - Lpri = LBASE x 4^2 = 21.6uH x 4^2 = 345.6uH
  - IR_Pri = IR_Base = 800mA
  - ISAT_Pri = 6/4 x ISAT_Base = 1.5 x 0.48A = 720mA
- Secondary has 2 coils in parallel and 2 current paths
  - IR_Sec = 2 x IR_Base = 1.6A
- All 6 coils are connected
  - No dangling coils!
- Dot convention is correct for our design

Our Transformer selection is complete! We still have to select our other components + design the control loop … WDS will do all of these
More details on our Analog Power Supply Design Workshop

Electrical Properties:

Properties	Test conditions		Value	Unit	Tol.
Inductance Base	100 kHz/ 100 mV	L_{BASE}	21.6	µH	±20%
Turns Ratio		n	1:1:1:1:1:1		
Voltage-µSecond Base		$\int Udt_{Base}$	63.4	µVs	max.
Rated Current Base	ΔT = 40 K	$I_{R\ BASE}$	0.8	A	typ.
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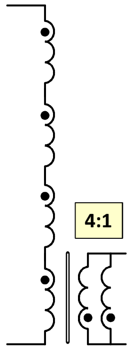
Insulation Test Voltage	all windings	U_T	1500	V (AC)	



* Full datasheet on: https://www.we-online.com/components/products/datasheet/749196218.pdf

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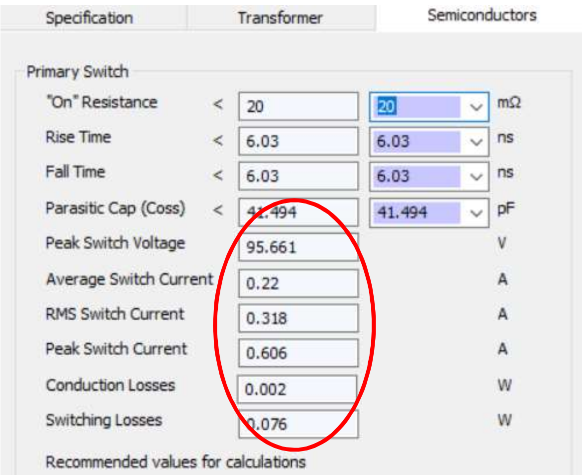
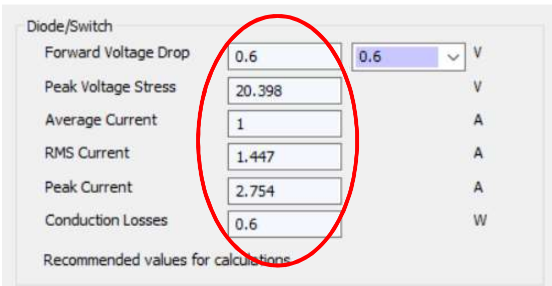
Completing the Design with WDS

- Silicon stresses and selection





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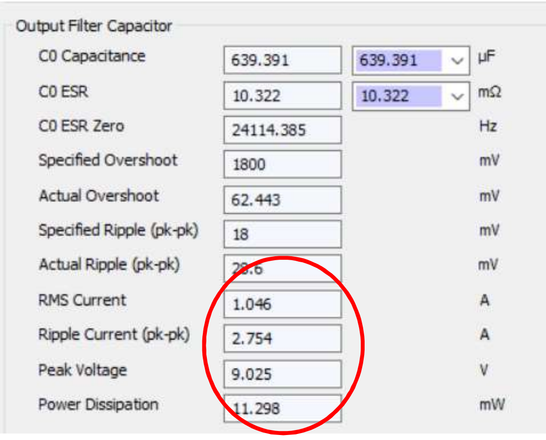
Completing the Design with WDS

- Output Caps selection and stresses
  - Calculated based on Vout ripple requirements and transient response that we specified earlier in the specification tab



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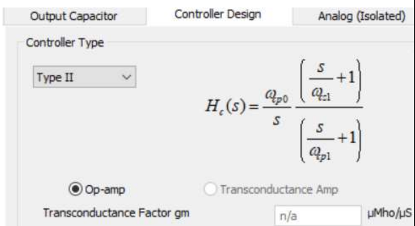
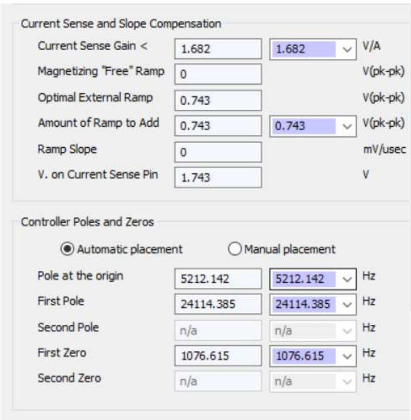
Completing the Design with WDS

- Current sense, slope compensation and control loop design





We talk about these in detail in our Analog Power Supply Design Workshops

www.biricha.com

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Completing the Design with WDS

- Opto-coupler, programmable reference and Isolated loop design does to component level

Optocoupler

Isolation Configuration	CNY17-3 5: *@ Vpullup=8V, Rpullup=2.		
Let Biricha characterize your opto			
Max. CTR		185	%
Typ. CTR		123	%
Min. CTR		61	%
Vpullup (Primary)		8	V
Vce(sat) (Primary)		0.25	V
Copto (Primary)		2.8	nF
Desired Ic Max. (Primary)		3.523	mA
Rpullup (Primary)	2.2	2.2	kΩ
Actual Ic Max. (Primary)	3.523		mA
Calculated If (Secondary)	2.864		mA
Vf (Secondary)		1.39	V

Divider and Error Amplifier

Error Amp Configuration	LMV431		
Vref - Min. Programmable Ref Voltage		1.24	V
Desired Ibias - Min. Cathode Current		0.2	mA
Rbias	6.95	6.95	kΩ
Actual Ibias	0.2		mA
Max. Cathode Current	3.064228		mA
Desired Ipd - Current through divider		0.25	mA
R1	31.04	31.04	kΩ
Actual Ipd	0.25		mA
R1 Power Dissipation	1.94		mW
Rb	4.96		kΩ
Rb Power Dissipation	0.31		mW

Full details on our Analog Power Supply Design Workshop

or see

Christophe Basso's great book on the subject
ISBN:978-1-608007-557-7

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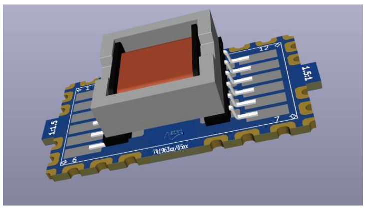
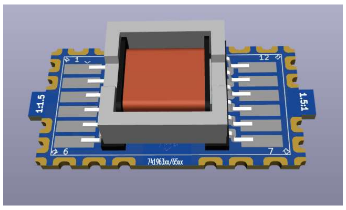
Coming Soon: New Online Workshop from Biricha

- Fast Flyback Design Online Workshop
  - Online workshop but with hands-on element
  - The objective is to help electronic engineers with little/no background in power supply design to design their DC/DC Flybacks FAST!
  - At the end of the workshop the attendees will have designed their Flyback "*down to the very last component*" based *on "their own spec"*
- To allow a dynamic specification based on the customers' own applications, we have designed set of Wurth Elektonik Flex transformer daughter cards with all the 9 turns ratios
  - All suitable transformer configuration will be available on daughter cards





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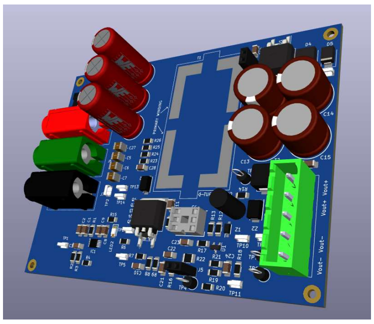
Coming Soon: New Online Workshop from Biricha



- We have also designed a DC/DC Flyback whose specification can be changed by the user
  - Will be available for sale from many major suppliers
  - Isolated Flyback - Vin <=52V, Vout 3.3 to 50V, Pout ~=10W
  - Multiple footprints for many of the components
  - Includes robust silicon with high ratings as well as protection/snubbers/clamp
- WDS + Biricha Flex Transformer spreadsheet can calculate all components based on the users specification and then the correct transformer daughter card can be soldered directly on the board
- Detailed online material, multiple design examples, workbooks, videos, tools, WDS, spreadsheets etc. will guide the students in a step-by-step manner to designs their power supply and get their product out of the door in record time
  - Not a single component omitted ☺
- The attendees can then design and test their power supply for their product with full confidence that at least there are no hardware bugs
- The online workshop will be available on teachable.com soon
  - We start with Isolated Flyback; other popular topologies will follow

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To be kept informed please register on our mailing list

www.biricha.com/news

The End of Presentation
Thank you very much for your time

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