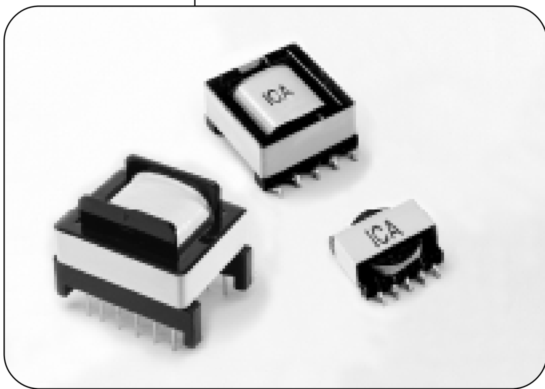
Switch Mode Power Supply Transformers



- **Economy series features low-cost, industry-standard sizes**
- **Performance series features SMT and low profiles**
- **Power range from 1 watt to 1,200 watts**
- **Frequency range to 500 KHz**
- **Can be designed to meet UL, CSA, VDE, CE or IEC standards**

DESIGNING AN SMPS TRANSFORMER

In designing a switch mode power supply, one of the most difficult but least understood elements is the transformer. ICE's goal is to simplify the transformer design process and thereby shorten the design cycle time. The first step is to define the SMPS parameters. This should include the following items: input voltage, secondary power output for each winding, switching frequency, I peak and the maximum allowable duty cycle. You will also need to choose the type of switching topology that you plan to use. Refer to ICE's application note on pg. 17 for more information on switching topologies.

Next is the easy part. **1** You can turn to page 21, fill out the SMPS custom design form and fax it to (703) 257-7547 or **2** Follow the step-by-step procedure on the next page to design your own SMPS transformer. When finished, fill out the bottom section of the custom design form on page 21 and fax it in. That's it, you're done! ICE will provide a quotation and samples and you can move on to other aspects of your design.

GLOSSARY

Np: Primary turn count

E-T: Volt-time product (Volt-microSecond)

B: Maximum flux density (Assume 3,000 Gauss)

Ae: Effective cross sectional area

Ns: Secondary turn count

Vs: Output voltage

Vd: Output rectifier and choke voltage drop

Ac: Bobbin window area

AeAc: The product of Ae and Ac

le: Magnetic path length

Ve: Effective volume

μi: Initial permeability

E ($^l/_A$): Core factor

D max.: Maximum duty cycle

Vdc min.: Minimum rectified input line voltage

Po: Output power

F: Frequency

PL: Power loss

I: The peak current in the winding

Lp: Primary inductance

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DESIGN PROCEDURE

The following design procedure will aid in the design of transformers for flyback, forward and push-pull topologies. The goal of the procedure is to get the engineer to a working prototype quickly. We have made some basic assumptions in this design procedure that will work for most designs. If you feel your application is more difficult than normal or you are designing a half or full bridge power supply we suggest you fill out ICE's custom design form on page 21 and let ICE engineers complete your design.

Before you get started, make a copy of ICE's custom design form and fill in the input voltage, secondary power output for each winding, switching frequency, I peak and the maximum allowable duty cycle.

STEP 1

Core Choice—Make your preliminary core choice based upon the power requirements of the application, the switching topology that you have chosen and the frequency. Refer to the graphs starting on the next page for reference.

STEP 2

E-T Value—Determine the E-T value based upon the maximum allowable duty cycle and the frequency. This formula will provide the answer in V-uSec.

$$\text{E-T} = \frac{1*10^6}{f}(\text{Dmax})(\text{Vdc min.})$$

STEP 3

Primary turn count—Determine the minimum number of primary turns required to support the worst case (E-T) volt-time product. For an exact value, use the formula below.

$$Np = \frac{\text{E-T} * 10^2}{B * Ae}$$

**(Ae values are listed in the tables on page 12)*

STEP 4

Turns Ratio—Calculate the second/primary turns ratio.

Flyback

$$\frac{Ns}{Np} = \frac{(Vs+Vd)\ (1-D)}{\text{Vdc min} * \text{Dmax}}$$

Forward Converter

$$\frac{Ns}{Np} = \frac{Vs+Vd}{\text{Vdc min} * \text{Dmax}}$$

Push-Pull Converter

$$\frac{Ns}{Np} = \frac{Vs}{\text{Vdc min} * \text{Dmax}}$$

STEP 5

Secondary turns—Choose the exact primary and secondary turn counts to be used based upon the Np and Ns/Np.

STEP 6

Primary inductance–Calculate the required primary inductance.

$$Lp = \frac{\text{eff}(\text{Vdc min} * \text{Dmax})^2}{2 * Po * F}$$

Note: The efficiency, at this point in the design, is an estimate. Use the following table to determine the value.

Topology	Efficiency Range
Flyback	75%–80%
Forward	80%–85%
Push-Pull	87%–92%

STEP 7

Air Gap—To calculate the air gap you must first determine the AL value required to achieve the primary inductance.

$$AL = \frac{L}{Np^2} \qquad \text{Air Gap} = \frac{1.257}{(\Sigma L/A) * AL} - \frac{1}{\mu i} * le$$

The air gap can now be calculated with the formula above.

Note: The push-pull and forward converter topologies typically do not require an air gap.

STEP 8

Wire Size—Find the wire size from the table on page 14. Assume 400 circular mils per one ampere. Total circular mils = 400 * I.

STEP 9

Fit Factor—Calculate the required winding window. The formula is: (wire dia.)^2 * (# of turns) for each winding. Add the total for all windings and compare the total to the allowable space (Ac) listed in the tables on page 12. Do not exceed 75% fill.

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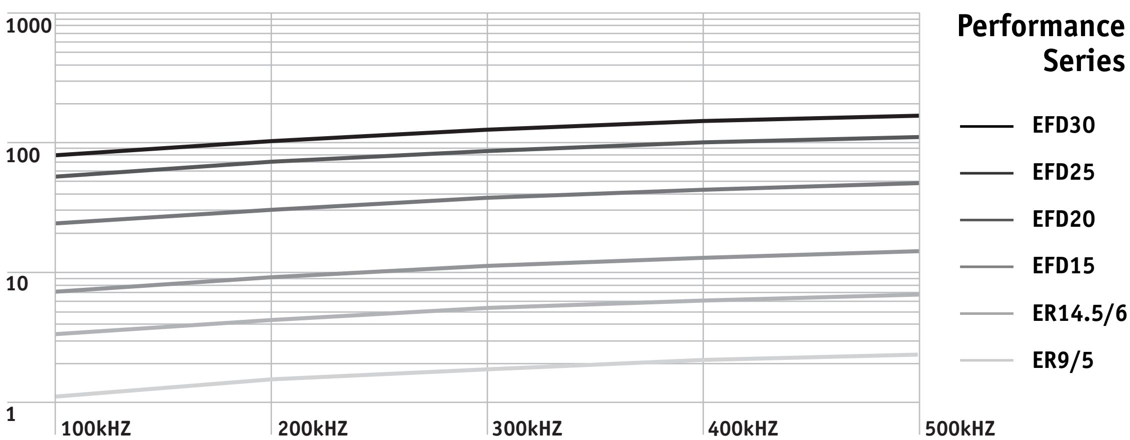
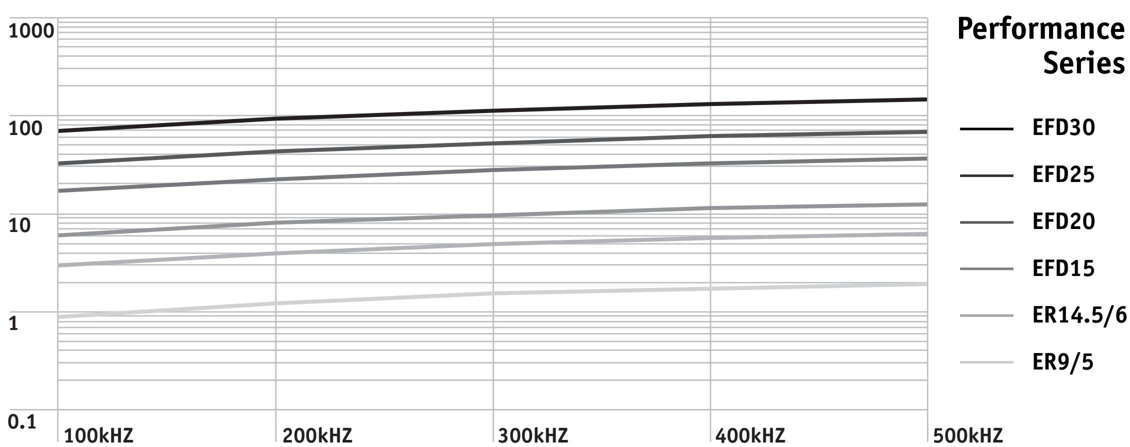
PERFORMANCE SERIES	PT-ER0905-XX	PT-ER1406-XX	PT-EFD15-XX	PT-EFD20-XX	PT-EFD25-XX	PT-EFD30-XX
Ac (cm2)	0.0306	0.055	0.167	0.29	0.402	0.523
Ae (cm2)	0.0847	0.176	0.122	0.31	0.58	0.69
AeAc (cm4)	0.0026	0.0097	0.0204	0.0899	0.2332	0.3609
le (cm)	1.42	1.9	3.4	4.7	5.7	6.8
Ve (cm3)	0.12	0.33	0.51	1.46	3.3	4.7
μi	1800	1800	1800	1800	1800	1800
$\Sigma(l/A)mm^{-1}$	1.67	1.08	2.27	1.52	1.00	0.98

ECONOMY SERIES	PT-EE25/06-XX	PT-EE35/10-XX	PT-EE41/13-XX	PT-EE42/15-XX	PT-EE42/20-XX	PT-EE55/21-XX
Ac (cm2)	0.53	0.95	1.24	1.95	1.95	3.23
Ae (cm2)	0.39	0.89	1.61	1.84	2.4	3.46
AeAc (cm4)	0.2067	0.8455	1.9964	3.588	4.68	11.17
le (cm)	4.90	7.30	8.27	10.32	10.32	13.08
Ve (cm3)	1.93	5.59	11.5	17.3	34.2	44.0
μi	2000	2000	2000	2000	2000	2000
$\Sigma(l/A)mm^{-1}$	1.24	0.85	0.517	0.548	0.417	0.35

POWER VS FREQUENCY—FORWARD CONVERTER



POWER VS FREQUENCY—FLYBACK CONVERTER



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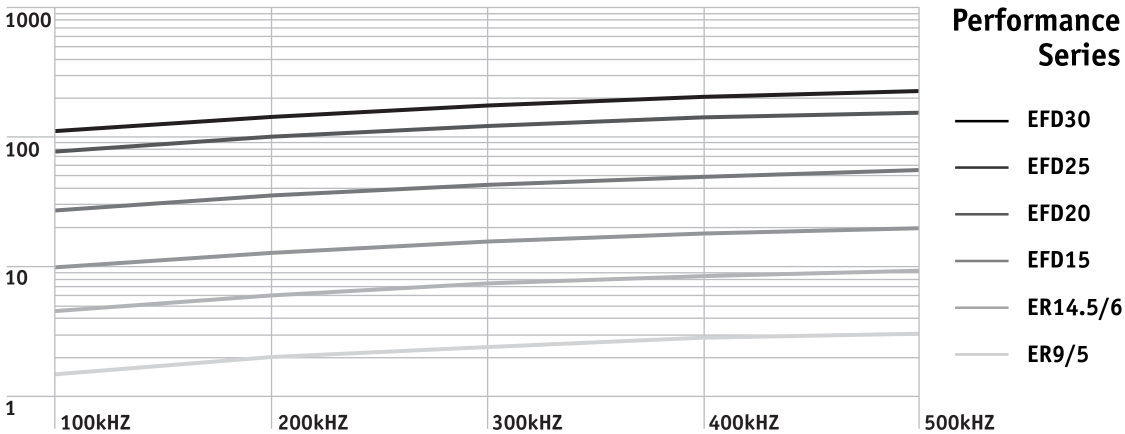
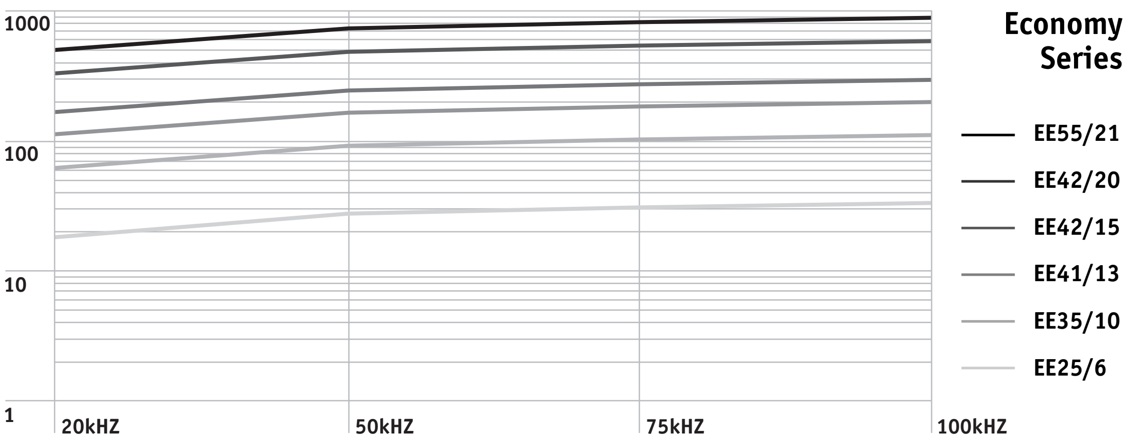
POWER VS FREQUENCY—PUSH-PULL CONVERTER



POWER VS FREQUENCY—FORWARD CONVERTER



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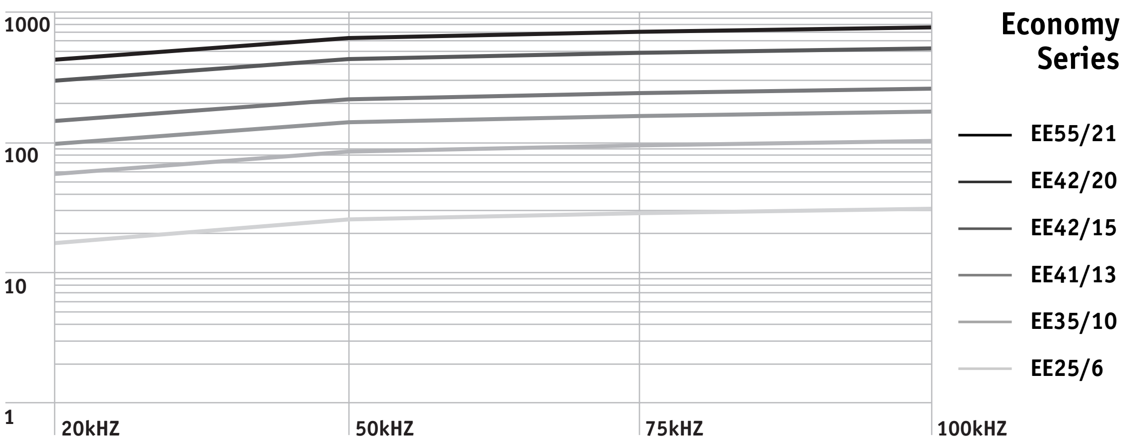
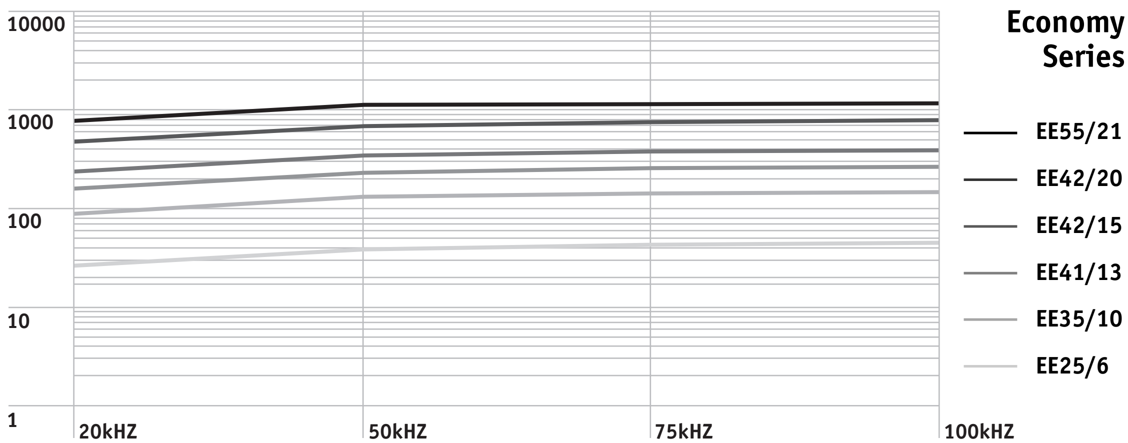


POWER VS FREQUENCY—PUSH-PULL CONVERTER

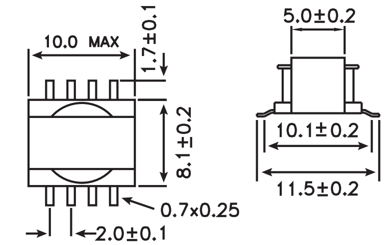


WIRESIZE SPECIFICATIONS

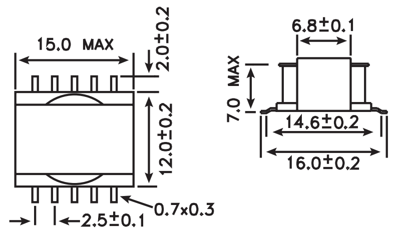
AWG	BARE dia (in)	BARE dia (mm)	lb/1kft wt	ohm/1kft res.	a. cir.mil
10	0.1019	2.58826	31.7	0.9985	10380
11	0.0907	2.30378	1.26	1.261	8230
12	0.0808	2.05232	20	1.588	6530
13	0.072	1.8288	15.9	2	5180
14	0.0641	1.62814	12.6	2.52	4110
15	0.0571	1.45034	10	3.18	3260
16	0.0508	1.29032	7.94	4.02	2580
17	0.0453	1.15062	6.32	5.05	2050
18	0.0403	1.02362	5.02	6.39	1620
19	0.0359	0.91186	3.99	8.05	1290
20	0.032	0.8128	3.17	10.1	1020
21	0.0285	0.7239	2.52	12.8	812
22	0.0253	0.64262	2	16.2	640
23	0.0226	0.57404	1.6	20.3	511
24	0.0201	0.51054	1.26	25.7	404
25	0.0179	0.45466	1	32.4	320
26	0.0159	0.40386	0.794	41	253
27	0.0142	0.36068	0.634	51.4	202
28	0.0126	0.32004	0.501	65.3	159
29	0.0113	0.28702	0.404	81.2	128
30	0.01	0.254	0.317	104	100
31	0.0089	0.22606	0.252	131	79.2
32	0.008	0.2032	0.204	162	64
33	0.0071	0.18034	0.161	206	50.4
34	0.0063	0.16002	0.127	261	39.7
35	0.0056	0.14224	0.101	331	31.4
36	0.005	0.127	0.081	415	25
37	0.0045	0.1143	0.065	512	20.2
38	0.004	0.1016	0.052	648	16
39	0.0035	0.0889	0.04	847	12.2
40	0.0031	0.07874	0.031	1080	9.61
41	0.0028	0.07112	0.025	1320	7.84
42	0.0025	0.0635	0.02	1660	6.25

MECHANICAL

ER9/5



ER14.5



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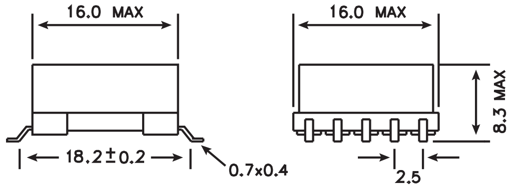

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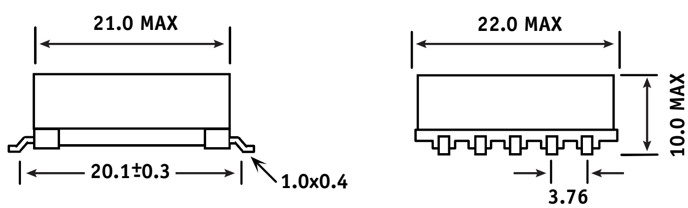

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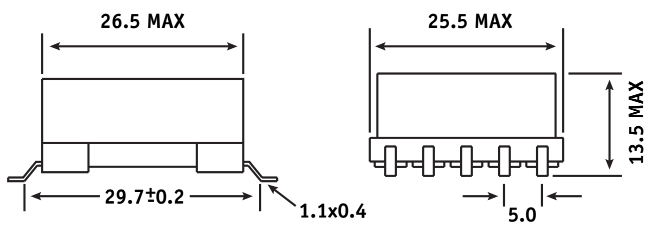

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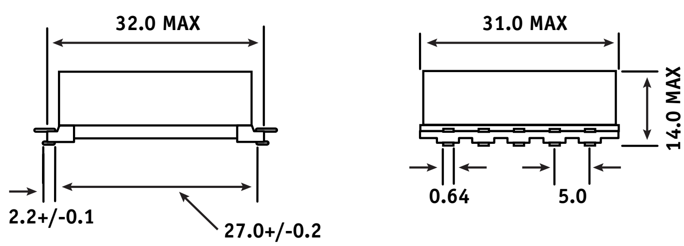

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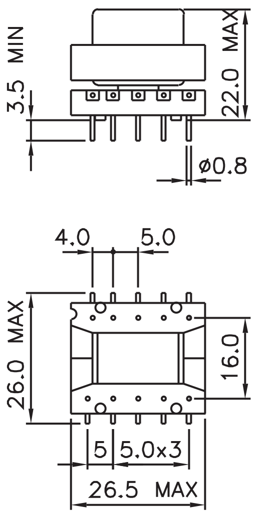

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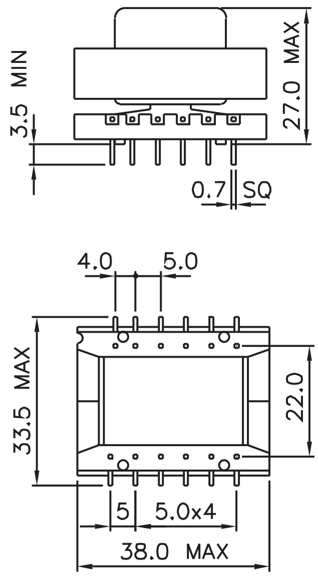

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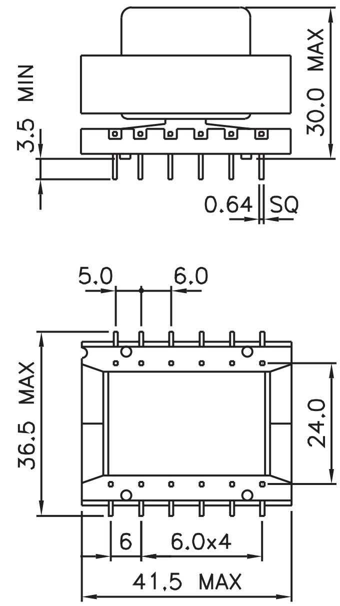

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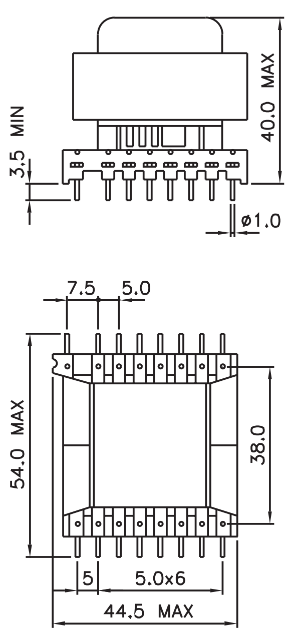

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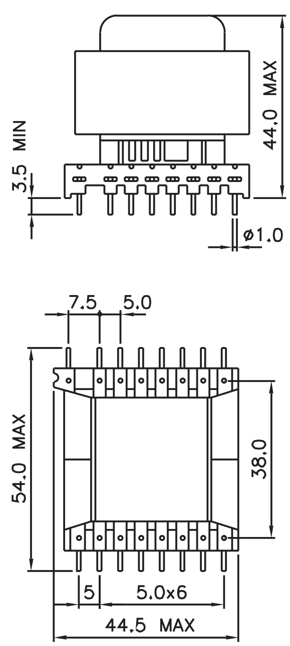

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