Integrated Digital Control

Application Note:
SYANL109
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Networkable Dimmable Electronic Ballast for 3xCFL 26W using PLC-Link™ Power Line Bi-Directional Communication. One pair of lamps in series connected in parallel with the third lamp.

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Introduction:

The present documents shows a reference design of a networkable electronic ballast of 3 compact fluorescent 26W lamps based on an ECO solution with one pair of lamps in series connection operating in true parallel with the third lamp. The pair of lamps and the third lamp can be separately controlled by PLC. This reference design is based on the IDC2000 controller with embedded PLC modem. This application also includes test results of the engineering prototypes, a non-networkable solution and components breakdown given for networkable and non-networkable models.

Detailed performances and features of this ballast are described in application note SYANL-105-1.

1. Ballast Characteristics

- Optimal preheat & ignition
- Dimmable: 2% - 100% light level
- Fully protected
- Operation of 1, 2 or 3 lamps
- A pair of lamps, or the third lamp, can be remotely and independently turned on and off
- The serially connected pair and the third lamp may have different light levels
- Remotely controlled by PLC (option)
- Optimized efficiency at all light levels
- High Power Factor – Low input current THD

Note: The ballast will be non-dimmable without the integration of the line coupler circuit.

The table below describes ballast performance: (CFL 26W lamps)

Light level [%]		105	101	97	90	84	77	64	47	30	20	10	5	2
DC Bus [V]		367	334	312	289	278	256	223	223	212	212	212	212	234
Input Power [W]	3 lamps	88.2	81.7	76.2	68.6	63.0	61.3	50.6	41.1	32.5	27.0	21.3	18.1	17.6
	2 lamps	60.0	55.5	51.8	46.7	42.8	41.8	34.4	28.0	22.0	18.3	14.5	12.4	12.0
	1 lamp	31.8	30.0	28.5	26.2	24.4	24.2	20.3	16.8	13.4	11.3	9.1	7.9	7.7
PF		0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
THD [%]		1.70	1.70	1.70	1.90	1.90	1.90	2.10	1.60	2.60	3.80	5.90	6.60	6.80
Lamp Voltage [V]		81.3	85.9	93.2	100	107	111	123	136	147	154	159	162	163
Lamp Current [mA]		303	272	232	190	162	140	108	70	44	29.5	16	10	7.5
Peak current [mA]		960	855	700	566	455	400	305	200	125	83	48	33	21
Current Crest factor (including the line frequency component)		1.56	1.55	1.51	1.49	1.40	1.43	1.41	1.43	1.42	1.41	1.50	1.65	1.40
Filament [V]		1.40	1.30	1.40	1.50	1.70	1.56	1.92	2.50	2.70	2.90	3.00	3.10	3.40
Light level [V]		5.28	5.07	4.90	4.55	4.24	3.87	3.22	2.35	1.52	1.01	0.50	0.25	0.12
Light level LF ripple (mV RMS)		26	24	11	10	5	4.5	4	5	7	5	3	3.5	2.7
Flicker [%]		0.5	0.5	0.2	0.2	0.1	0.1	0.1	0.2	0.5	0.5	0.6	1.4	2.3
BEF Ballast Efficacy Factor	3 lamps	1.19	1.24	1.27	1.31	1.33	1.26	1.27	1.14	0.92	0.74	0.47	0.28	0.11
	2 lamps	1.75	1.82	1.87	1.93	1.96	1.84	1.86	1.68	1.36	1.09	0.69	0.40	0.17
	1 lamp	3.30	3.37	3.40	3.44	3.44	3.18	3.15	2.80	2.24	1.76	1.09	0.63	0.26

2. Ballast Bill of Materials (BOM)

Refer to component notes in Section 3

Item	Quantity	Reference	Part
		A1	Line Coupler (see Note 1)
1	5	C1, C2, C10, C20, C31	0.22UF 400V Met. Polyester (see Note 2)
2	4	C9, C13, C12, C29	1nF 250VAC Y2
3	1	C8	4.7nF 250VAC X2
4	2	C52,C24	4.7nF 1.6KV Met. Polypropylene
5	1	C5	22uF 450V Electrolytic
6	2	C27, C26	100uF 6.3V Electrolytic
7	1	C22	10uF 25V Electrolytic
8	1	C3	22pF 500V
9	5	C14, C23, C36, C42, C54	330nF 50V 10% Ceramic thru hole
10	17	C4, C6, C7, C30, C43, C44, C47, C48, C49, C61, C64, C65, C66, C67, C68, C69, C70	0.1uF 10% 0805
11	2	C58, C17	10nF 10% 0805
12	2	C45, C46	15pF 10% 0805
13	1	C59	100pF 10% 0805
14	1	C62	470pF 10% 0805
15	2	C16, C71	47pF 10% 0805
16	1	D1	MUR160
17	2	D7, D38	HER106
18	5	D37, D40, D41, D42, D43	1N4007
19	1	D24	LM431
20	13	D8, D10, D12, D16, D19, D20, D21, D22, D23, D30, D31, D32, D39	1N914B
21	1	F1	2A
22	2	J4,J5	6 pin lamp connector
23	1	J1	LINE INPUT
24	1	L1	Diff U100W Core: Micrometals T68-26 (optional for better filtering of input)
25	1	L2	PFCC-U100W Core: EF25
26	1	L3	Comm.Mode U100W Core: EF25
27	1	L4	BAL_S2L Core: EF25
28	1	L5	BAL_1L Core: EF20
29	1	Q1	IRF840
30	4	Q2, Q3, Q4, Q5	IRF830
31	1	Q9	2N2222A
32	1	R2	NTC (see Note 3)
33	1	R1	0.47 1W 1%
34	2	R4,R9	332K 0.25W 1% TH
35	1	R5	20K 0.25W 5% TH
36	1	R11	3.57K 0.25W 1% TH
37	4	R15, R17, R18, R20	100K 0.25W 1% TH
38	9	R21, R23, R24, R26, R30, R43, R44, R65, R66	150K 0.25W 5% TH
39	2	R29, R52	10Ω 0.25W 1% TH
40	5	R3, R8, R13, R74, R68	30Ω 5% 0805
41	3	R28, R48, R63	200Ω
42	2	R22, R42	5.1K 5% 0805

Ballast BOM (cont.)			
Item	Quantity	Reference	Part
43	3	R14, R25, R67	2.7K 5% 0805
44	2	R27, R47	2K 5% 0805
45	2	R31, R53	10Ω 5% 0805
46	1	R46	100K 5% 0805
47	1	R64	3.9k 5% 0805
48	1	R65	470 1% 0805
49	1	R66	10k 1% 0805
50	1	T1	Auxiliary PS transformer Core: EF16
51	1	U1	IDC2040
52	2	U3, U4	IR2101S (see Note 4)
53	1	U2	Single low side driver TC1410N (see Note 5)
54	1	U6	TNY253G off-line regulator (see Note 6)
55	1	VR1	Varistor 5J
56	1	Y1	CRYSTAL 12MHz 100ppm
	134	**Total components count**	

3. Component Notes to Ballast BOM

These notes refer to Section 2 above.

1. Item 0 -A1 – Sub-assembly see schematic and BOM options in this document.
2. Item 1 -C1 – Filter capacitor 0.22µF and Item 25 -L1 – Line filter differential inductor: **optional** to comply with European standard EN50065 for electromagnetic disturbance.
3. Item 32 -R2 – NTC **optional,** added to the circuit to decrease inrush current each time the ballast is connected to the line. This component can be eliminated if the ballast is permanently connected to line.
4. Item 52 – U3, U4 – IR2101 High side driver and low side driver for half bridge, made by International Rectifier (IR).
5. Item 53 – U2 – TC1410 single non-inverting low side driver made by Microchip.
6. Item 54 – U6 – TNY253G Off-line regulator for the ballast auxiliary voltages. Chip made by "Power Integrations" and can be replaced by "VIPer12" from STmicroelectronics with slight changes.
7. Magnetic components: For design examples of the magnetic components see Magnetic Components Specifications of the 100W Ballast in application note SYANL105-1.

4. PLC Line Coupler (Reference A1 in Ballast BOM)

4.1. PLC Line Coupler - Alternative I based on OPA561 Linear Power Amplifier from TI. Similar designs can be made using DSL amplifiers. See note below.

Item	Quantity	Reference	Part
1	1	C81	470nF 250VAC
2	2	C79, C77	220uF 16V Electrolytic
3	4	C78, C82, C83, C88	0.47uF 10% 0805
4	1	C84	22nF 10% 0805
5	4	C72, C74, C75, C76	10nF 10% 0805
6	1	C71	3.3nF 10% 0805
7	2	C86, C87	2.2nF 10% 0805
8	2	C80, C85	1nF 10% 0805
9	2	D38, D39	D1N4734A
10	1	L11	200uH Axial Lead 0.25"
11	2	L12, L13	10uH Axial Lead 0.25"
12	2	L14, L15	2mH Axial Lead 0.25"
13	1	R64	1.5K 5% 0805
14	1	R65	2K 5% 0805
15	1	R66	620Ω 5% 0805
16	2	R70, R67	6.2K 5% 0805
17	1	R68	100Ω 5% 0805
18	1	R69	1K 5% 0805
19	1	R71	3K 5% 0805
20	1	R72	18K 5% 0805
21	1	R73	300Ω 5% 0805
22	1	T2	PLCD_Trafo Core: EF16
23	1	U3	OPA561 (TI) (see note 1)
	36	**Total components count**	

Note 1:

Item 23 – U3 - OPA 561 is a wideband power amplifier from TI that has the characteristics to make a premium PLC transmitter at the requested frequency band. A good replacement for this component can be one of a large variety of existing DSL amplifiers such us AD8017, AD8019 and AD8391 from Analog Devices or EL1519 from Intersil. Of course the electrical circuit will need to be changed slightly.

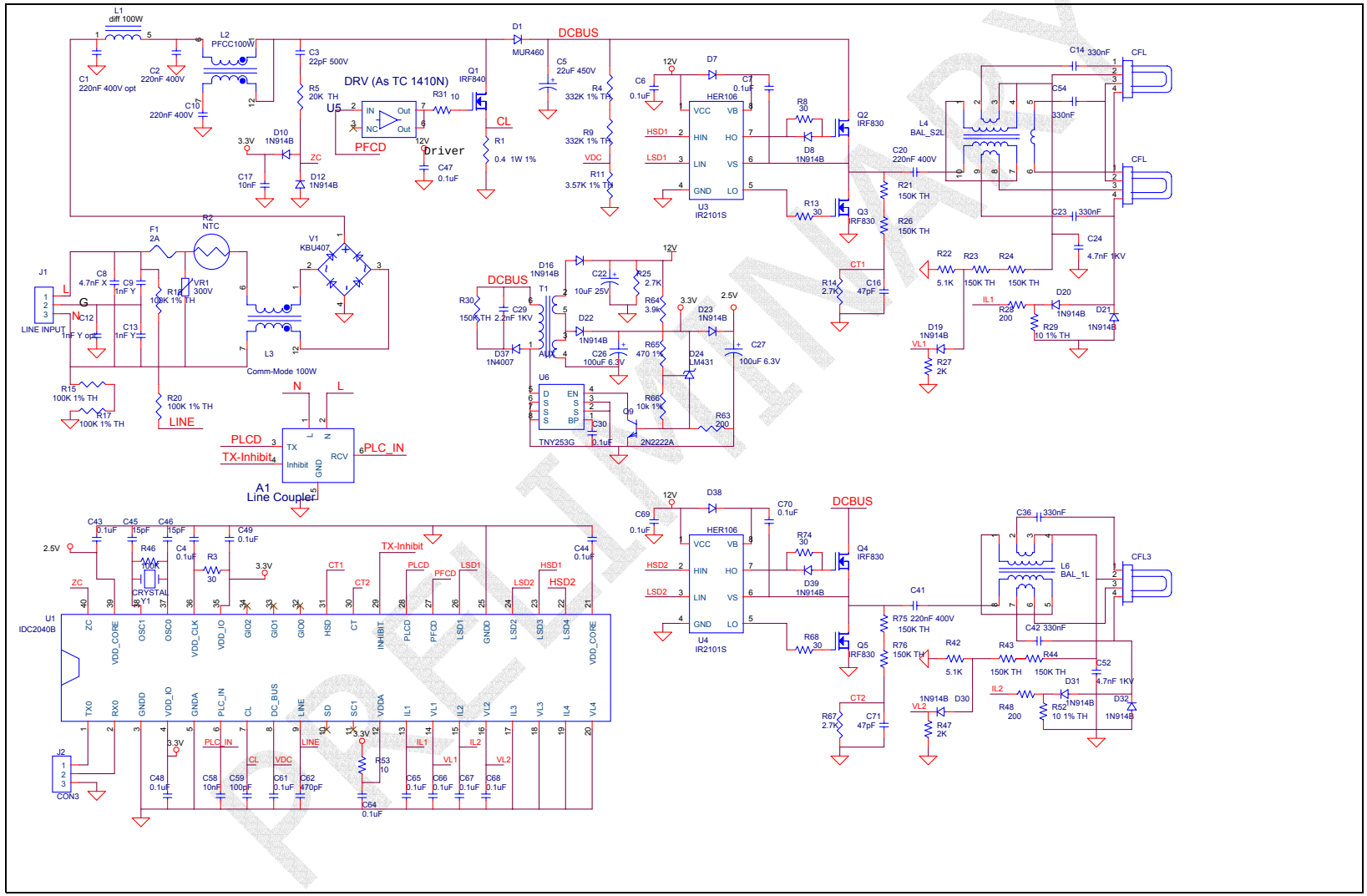
4.2 PLC Line Coupler - Alternative II

PLC Transmitter Class D Power Amplifier based on TC1428 or similar dual gate driver.

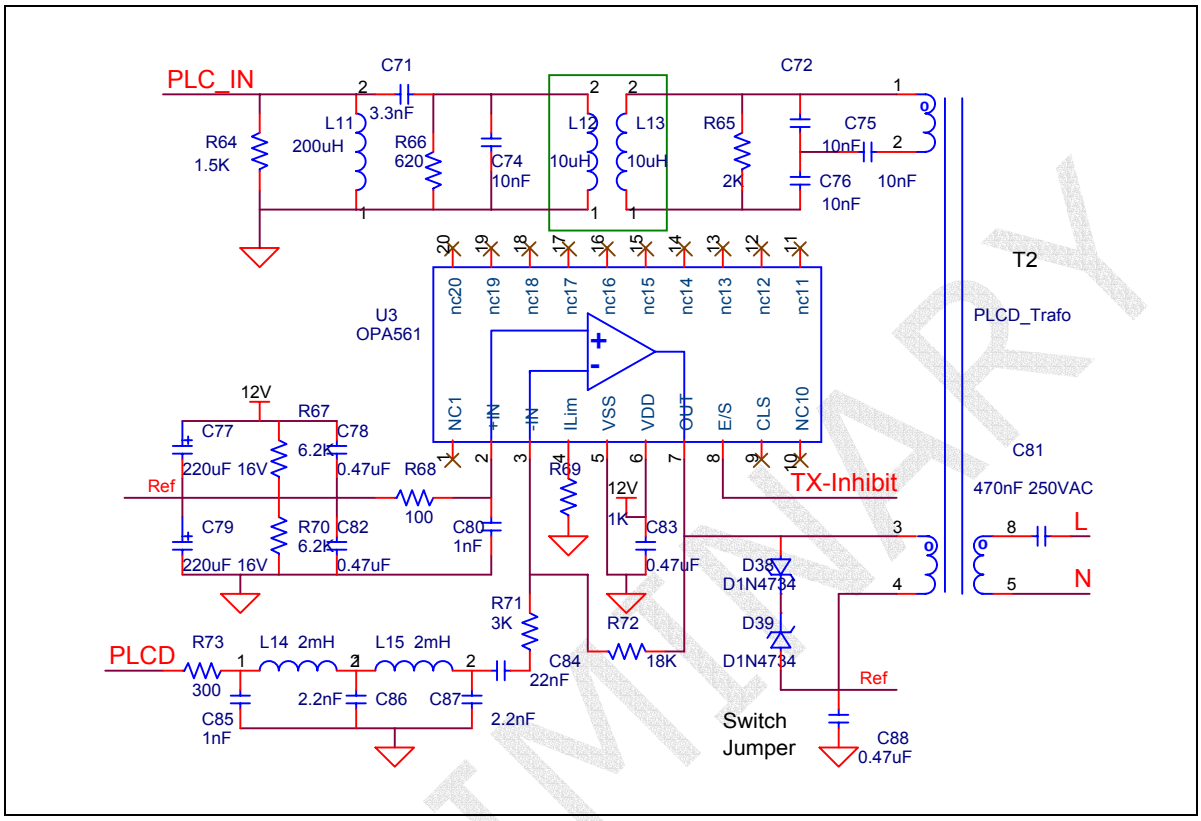
Item	Quantity	Reference	Part
4	1	C8	22n 250VAC X2
3	1	C7	0.47uF 10% 0805
5	1	C9	100nF 10% 0805
6	1	C10	22nF 10% 0805
7	1	C11	18nF 10% 0805
2	5	C2, C3, C4, C5, C6	10nF 10% 0805
1	1	C1	3.3nF 10% 0805
8	2	D1, D2	1N4744A
9	1	L1	200uH Axial Lead 0.25"
10	2	L3, L2	10uH Axial Lead 0.25"
11	2	L4, L6	68uH Axial Lead 0.25"
12	2	L7, L5	75uH Axial Lead 0.25"
13	1	R1	1.5K 5% 0805
14	1	R2	620Ω 5% 0805
15	1	R3	2K 5% 0805
16	1	T1	PLCD_Trafo Core: EF16
17	1	U1	Dual gate driver (as TC1428) (see note below)
	25	**Total components count**	

This solution uses a bridge driver made of two complementary drivers: one inverting and one non-inverting (Item 17 U1 TC1428).

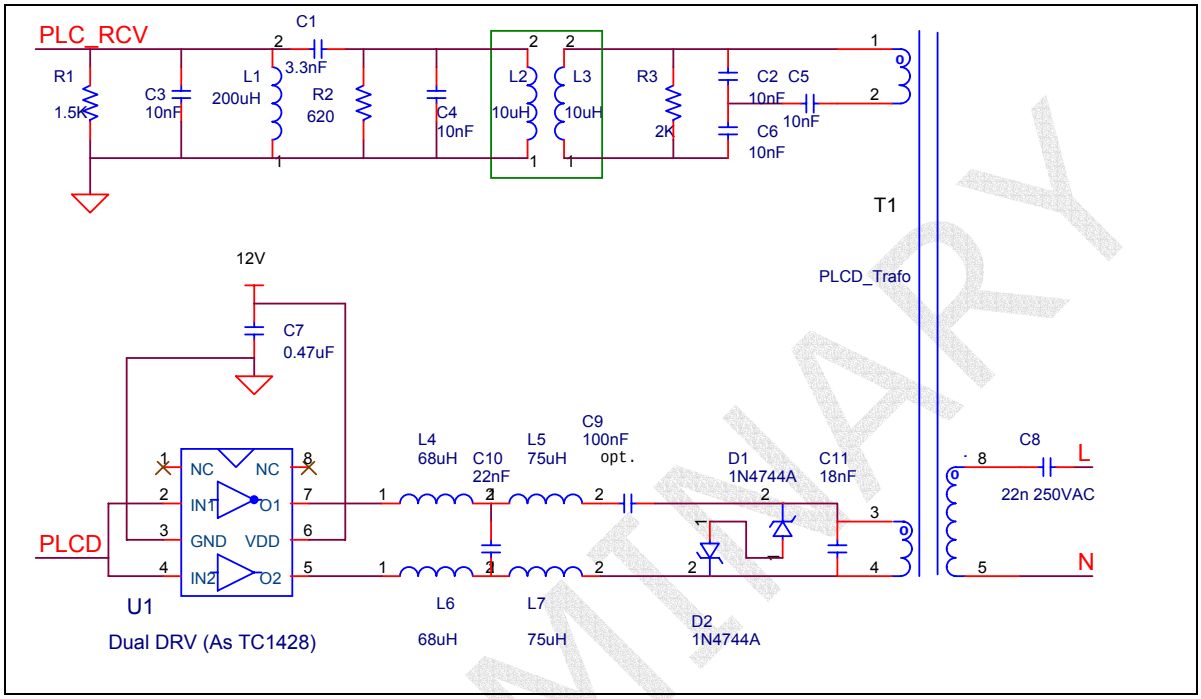
5. Dimmable Electronic Ballast for 3 Lamps (2+1)



6. PLC Line Coupler Alternative I with Linear Power Amplifier OPA 561



7. PLC Line Coupler Alternative II with Class D Power Amplifier based on Dual gate driver TC1428, or similar



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