Philips bipolar transistors for electronic lighting

Introduction

The Philips Technical Publication "Efficient Fluorescent Lighting using Electronic Ballasts" provides an introduction to fluorescent lamps and the circuits required to operate them with maximum life and efficiency. It introduces four simplified electronic ballast topologies which are suitable for operation on mains supplies. This Factsheet summarises those topologies and the theoretical voltage demands which they impose on the switching transistors. It concludes with selection guides & application recommendations.

High speed bipolars

Philips Semiconductors has introduced a new range of bipolar power transistors designed for lighting: the **BUJxxx range**. They exhibit a very fast switching performance and consequent low power dissipation. Their high performance allows the production of cool-running, efficient, low cost electronic ballasts for fluorescent lamps, and electronic transformers for low voltage tungsten halogen lamps.

a) vfpp - voltage fed push pull inverter

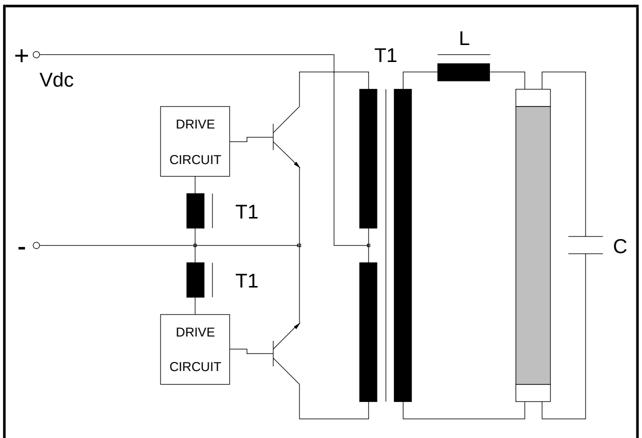

Fig. 1. Voltage fed push pull.

"Push-pull" topologies require a centre-tapped transformer. This allows the provision of isolation between the mains supply and the ballast output if required. It also enables output voltage to be optimised by the primary:secondary winding ratio.

The DC rail voltage appears at the transformer centre tap. Therefore $V_{ct} = V_{DC}$.

Half of the transformer's primary winding is energised with the full DC rail voltage at any one time. As for an autotransformer, twice this voltage will appear across the whole winding. This voltage appears across each transistor in turn when it is non-conducting, so:

$$V_{CE(max)} = 2 \times V_{DC}.$$

The ballast inductor L limits the lamp running current to the correct value. The starting capacitor C draws preheat current through the lamp filaments to assist in warm starting of the lamp.

The combination of the series L and the parallel C also serve to filter the harmonics of the square wave output of the inverter to leave an ideal near-sinewave current to drive the lamp. This maximises lamp life and minimises radiated interference.

b) cfpp - current fed push pull inverter

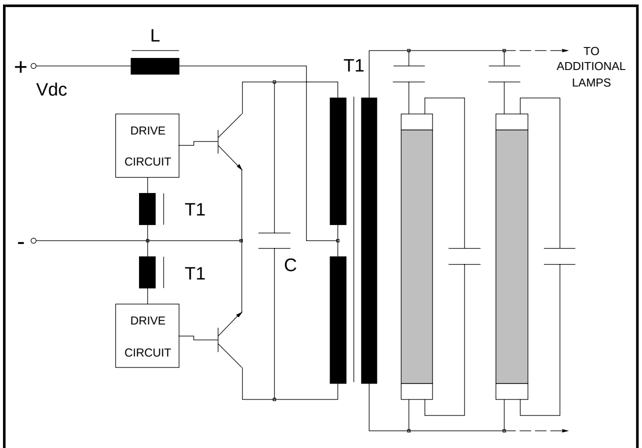

Fig. 2. Current fed push pull.

The transformer centre tap is now connected to the DC rail via a series inductor L which acts as a current source. The voltage developed across L as each transistor conducts results in a positive half sinewave at the centre tap whose average voltage is equal to the DC rail voltage. Therefore $V_{ct(av)} = V_{DC}$.

The peak value of this waveform can be shown by integration to be $\pi/2$ x its average value. Therefore $V_{ct(pk)} = \pi/2 \times V_{ct(av)} = \pi/2 \times V_{DC}$.

Each successive half sine is conducted through alternate halves of the primary. As for example a), the autotransformer effect results in twice the centre tap voltage appearing across the full primary winding. This voltage appears across the non-conducting transistor, so:

$$V_{CE(pk)} = \pi \times V_{DC}.$$

Because of the inherent sinusoidal output of this inverter, no filtering of harmonics is required on its output. It is therefore possible to use a ballast capacitor in series with the lamp. More than one lamp can be connected in parallel across the inverter's output.

The starting capacitors across the lamps serve the same function as in example a) above. Their capacitance will be much lower than that of the ballast capacitors.

c) cfhb - current fed half bridge inverter

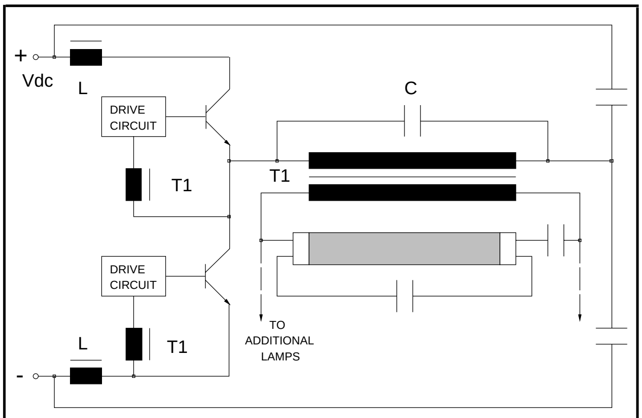

Fig. 3. Current fed half bridge.

As this is not a push-pull circuit a transformer is strictly not necessary. However this particular implementation of the cfhb inverter uses a transformer for isolation purposes and for optimisation of the output voltage prior to lamp ballasting.

The transformer primary is driven at one end by the collector-emitter junction point of the two transistors. The return current flows to the power supply rails via the half bridge capacitors.

If this were a voltage fed circuit without a current source inductor, the primary would be alternately connected to the positive and negative rails by the alternate transistor switching to produce a square wave with a peak to peak amplitude of V_{DC}. However, because this is a current fed resonant circuit, the conduction of each transistor will produce a half sine whose average voltage is equal to the DC rail voltage. Therefore $V_{(av)} = V_{DC}$.

By integrating it can be shown that the half sine will have a peak amplitude of $\pi/2$ x its average value. Therefore $V_{(pk)} = \pi/2 \times V_{(av)} = \pi/2 \times V_{DC}$.

This voltage appears across the non-conducting transistor, so:

$$V_{CE(pk)} = \pi/2 \times V_{DC}.$$

As this is a current fed inverter (due to the current source formed by inductor L in series with the power supply rails) its output is inherently sinusoidal. As for example b) it is possible to use a capacitor to ballast the lamp. More than one lamp can be connected in parallel, each with its own ballast capacitor.

d) vfhb - voltage fed half bridge inverter

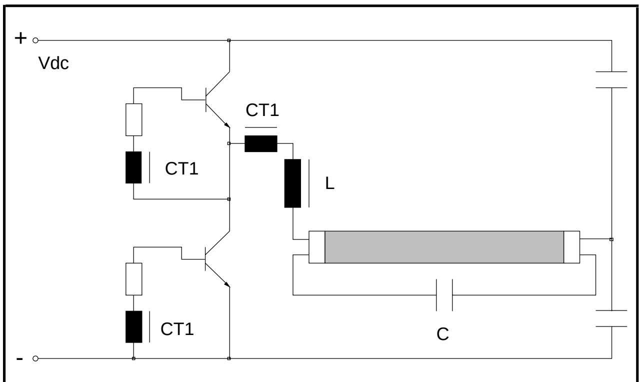

Fig. 4. Voltage fed half bridge.

This implementation of the vfhb inverter omits the transformer-isolated output. Lamp drive is taken, via the ballast inductor L, from the collector-emitter junction point of the two transistors. As the transistors are now connected directly to the DC rails, their alternate switching will switch the output between the DC rails only. Therefore $V_{(max)} = V_{DC}$.

As this voltage appears across the non-conducting transistor:

$$V_{CE(max)} = V_{DC}.$$

Current transformer CT1 provides base drive feedback for the transistors. It performs the same function as the auxiliary feedback windings on the transformers in the three previous topologies.

The voltage fed half bridge topology is the most popular choice for compact fluorescent lamps (CFLs), commercial/industrial fluorescent lighting ballasts and electronic transformers. It provides the cheapest and the easiest route to an efficient and reliable design.

The transistor voltage requirements are the lowest of all four topologies. This gives the designer the widest choice of the fastest switching bipolar transistors, since the lower the transistor's voltage rating, the faster its switching performance.

In the case of electronic transformers for low voltage tungsten halogen lamps, the ballast components would be replaced by a step-down transformer connected between CT1 and the half bridge capacitors. Its output would supply the 11.8V AC required to operate the lamps.

Selection guide

TO220 part numbers*	V_{CES} (V max)	V_{CEO} (V max)	$I_{C(DC)}$ (A max)	I_{Csat} (A max)
BUJ100A	700	400	1.0	0.5
BUJ101A			2.0	1.0
BUJ102A			4.0	2.0
BUJ103A			6.0	3.0
BUJ104A			8.0	4.0
BUJ105A			10.0	5.0
BUJ106A			12.0	6.0
BUJ200A	850	450	1.0	0.5
BUJ201A			2.0	1.0
BUJ202A			4.0	2.0
BUJ203A			6.0	3.0
BUJ204A			8.0	4.0
BUJ205A			10.0	5.0
BUJ206A			12.0	6.0
BUJ300A	1000	500	1.0	0.5
BUJ301A			2.0	1.0
BUJ302A			4.0	2.0
BUJ303A			6.0	3.0
BUJ304A			8.0	4.0
BUJ305A			10.0	5.0
BUJ306A			12.0	6.0
BUJ400A	1200	550	1.0	0.5
BUJ401A			2.0	1.0
BUJ402A			4.0	2.0
BUJ403A			6.0	3.0
BUJ404A			8.0	4.0
BUJ405A			10.0	5.0
BUJ406A			12.0	6.0
BU1706A	1750	850	5.0	1.5

Table 1. Philips bipolar transistors for lighting.

*Packages

Devices can be supplied in the following packages (transistor die-size constraints will apply for the smaller packages):

SOT78 (TO220) for non-isolated through-hole mounting (part numbers as shown in the table).

SOT186A for isolated through-hole mounting (add "X" to the part number - e.g. BUJ402AX).

SOT404 (D^2PAK) for surface mounting (add "B" to the part number - e.g. BUJ203AB).

SOT428 (DPAK) for lower power surface mounting (add "S" to the part number - e.g. BUJ100AS).

If required, the smaller transistors can be supplied in **SOT82** or **IPAK** (leaded DPAK) packages for through-hole mounting in lower power ballasts and CFLs.

Typical applications

Table 2 lists the most suitable transistors for each topology on different AC supplies. An assumption is made that the ballast's DC rail is obtained from rectified and smoothed AC mains. If boost power factor correction is included which boosts the DC rail voltage to around 400V irrespective of the mains voltage, the suggested transistors for 277V mains should be selected. Suggested ballast/transformer output powers are given.

Key to applications:

1 - Compact Fluorescent Lamp (CFL).

2 - Commercial/industrial fluorescent lighting ballast.

3 - Electronic transformer for low voltage tungsten halogen lamps.

AC supply	Suggested topologies, output powers & applications											
	a) vfpp			b) cfpp			c) cfhb			d) vfhb		
115V	BUJ100A	18W	*2*	BUJ300A	28W	*2*	BUJ100A	14W	*2*	BUJ100A	9W	*1*
	BUJ101A	36W	*2*	BUJ301A	56W	*2*	BUJ101A	28W	*2*	BUJ101A	18W	*1,2*
	BUJ102A	72W	*2*	BUJ302A	112W	*2*	BUJ102A	56W	*2*	BUJ102A	36W	*1,2*
	BUJ103A	107W	*2*	BUJ303A	169W	*2*	BUJ103A	84W	*2*	BUJ103A	54W	*1,2,3*
	BUJ104A	143W	*2*	BUJ304A	225W	*2*	BUJ104A	112W	*2*	BUJ104A	72W	*2,3*
	BUJ105A	179W	*2*	BUJ305A	281W	*2*	BUJ105A	141W	*2*	BUJ105A	90W	*2,3*
	BUJ106A	215W	*2*	BUJ306A	337W	*2*	BUJ106A	169W	*2*	BUJ106A	107W	*2,3*
230V	BUJ400A	36W	*2*	BU1706A	225W	*2*	BUJ300A	28W	*2*	BUJ100A	18W	*1,2*
	BUJ401A	72W	*2*				BUJ301A	56W	*2*	BUJ101A	36W	*1,2*
	BUJ402A	143W	*2*				BUJ302A	112W	*2*	BUJ102A	72W	*2,3*
	BUJ403A	215W	*2*				BUJ303A	169W	*2*	BUJ103A	107W	*2,3*
	BUJ404A	286W	*2*				BUJ304A	225W	*2*	BUJ104A	143W	*2,3*
	BUJ405A	358W	*2*				BUJ305A	281W	*2*	BUJ105A	179W	*2,3*
	BUJ406A	430W	*2*				BUJ306A	337W	*2*	BUJ106A	215W	*2,3*
277V & most boost pfc designs	BU1706A	172W	*2*	BU1706A	271W	*2*	BUJ400A	34W	*2*	BUJ200A	22W	*2,3*
							BUJ401A	68W	*2*	BUJ201A	43W	*2,3*
							BUJ402A	135W	*2*	BUJ202A	86W	*2,3*
							BUJ403A	203W	*2*	BUJ203A	129W	*2,3*
							BUJ404A	271W	*2*	BUJ204A	172W	*2,3*
							BUJ405A	339W	*2*	BUJ205A	216W	*2,3*
							BUJ406A	406W	*2*	BUJ206A	259W	*2,3*

Table 2. Bipolar transistors for lighting - suggested uses.

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