Supertex inc.

HV803, HV8051, and HV8053 EL Lamp Driver Circuits

Introduction

This application note describes the operation of Supertex EL (Electroluminescent) lamp drivers, provides guidelines for proper driver circuit design, and includes example circuits.

Supertex EL lamp drivers consist of two functional sections integrated on-chip: a power conversion section to boost supply voltage to levels required by EL lamps; and the lamp driver section to provide high voltage AC lamp excitation. Adjustments in both sections affect current consumption, lamp brightness, and lamp life. Adjustments in the lamp driver section also affect lamp hue, while adjustments in the power converter section ensure system compatibility. As each section is independently configurable, maximum flexibility is afforded the design engineer to optimize a circuit for a particular application.

EL Lamp Selection

Any design of an EL lamp circuit begins with the selection of an EL lamp. EL lamps are typically constructed as shown in Figure 1. Because EL lamps are a laminate, they exhibit a capacitance on the order of 2.5nF to 3.5nF per square inch. When high voltage is applied across the electrodes, the resulting electric field excites the phosphor atoms to a higher energy state. When the electric field is removed, the atoms fall back to a lower energy state, emitting photons in the process. The wavelength of the emitted light is determined by the type of phosphor used and the frequency of the excitation voltage. With most phosphors, the spectrum of emitted light will tend to shift towards blue with an increase in excitation frequency. Color is usually controlled, however, by selecting the phosphor type, by adding fluorescent dyes in the phosphor layer, through the use of a color filter over the lamp, or a combination of these.

EL lamp brightness increases approximately with the square of applied voltage. Increasing frequency, in addition to affecting hue, will also increase lamp brightness, but with a nearly linear relationship. (Most lamp manufacturers publish graphs depicting these relationships for various types of lamps.) Excitation voltages usually range from $60V_{P-P}$ to $200V_{P-P}$ at 60Hz to 1kHz. Increased voltage and/or frequency, however, adversely affects lamp life, with higher frequencies generally decreasing lamp life more than increased voltage. EL lamps, unlike other types of light sources, do not abruptly fail. Instead, their brightness gradually decreases through use. For intermittent use, lamp life is seldom a concern. For example, if a lamp is used 20 minutes per day, over the course of 10 years the lamp will be activated for a total of 1,216 hours, well within the useful life of most every EL lamp available. When designing a drive circuit, a balance needs to be struck between lamp brightness, hue, useful life, and supply current consumption.

Once a lamp has been selected, and operating voltage and frequency determined, design of the driver circuit can begin.
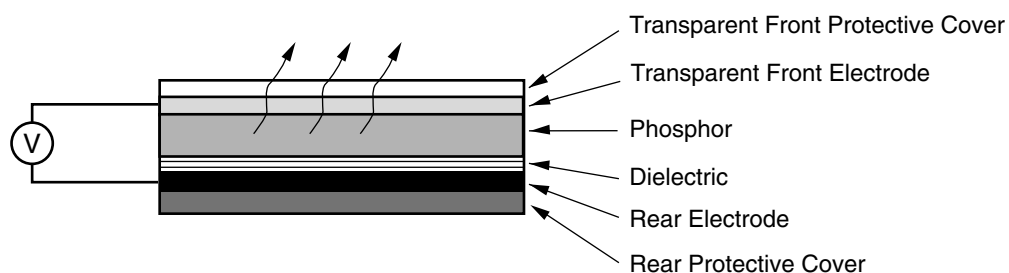

Figure 1: EL Lamp Construction

Power Converter Section

To generate the high voltages needed for driving EL lamps, Supertex drivers employ switch-mode converters using inductive flyback. By integrating high voltage transistors on-chip, these drivers avoid the need for expensive, bulky, and noisy transformers to generate high output voltages. Conversion frequency is controlled by an external resistor, allowing the circuit designer flexibility in selecting a frequency that optimizes performance while avoiding potential interference with nearby circuitry.

Referring to Figures 2 and 3, the power conversion cycle begins when MOSFET switch Q is turned on and current begins rising in inductor L. When Q is turned off, inductive flyback causes the voltage across the inductor to reverse polarity and rise until it reaches the level of the storage capacitor C_S, (plus diode drop) at which point the rectifier conducts and the energy contained in the magnetic field of the inductor is transferred to C_S. When all the inductor energy is transferred and inductor current drops to zero, the rectifier stops conducting and inductor voltage drops to zero, ready for the next cycle. Output power is simply the amount of energy transferred per cycle multiplied by the number of cycles per second.

$$\text{Inductor Current:} \quad I_L = \frac{V_{IN}}{R_{SW} + R_L}\left[1 - e^{-t_{ON}\left(\frac{R_{SW} + R_L}{L}\right)}\right] \qquad \text{Eq 1}$$

$$\text{Inductor Energy:} \quad W_L = \frac{1}{2}L I_L^2 \qquad \text{Eq 2}$$

$$\text{Output Power:} \quad P_O = f_c\,(W_L - W_{R_L}) \qquad \text{Eq 3}$$

$$\text{Inductor Loss:} \quad W_{RL} \approx \frac{1}{3}R_L I_L^2 t_d \qquad \text{Eq 4}$$

where:
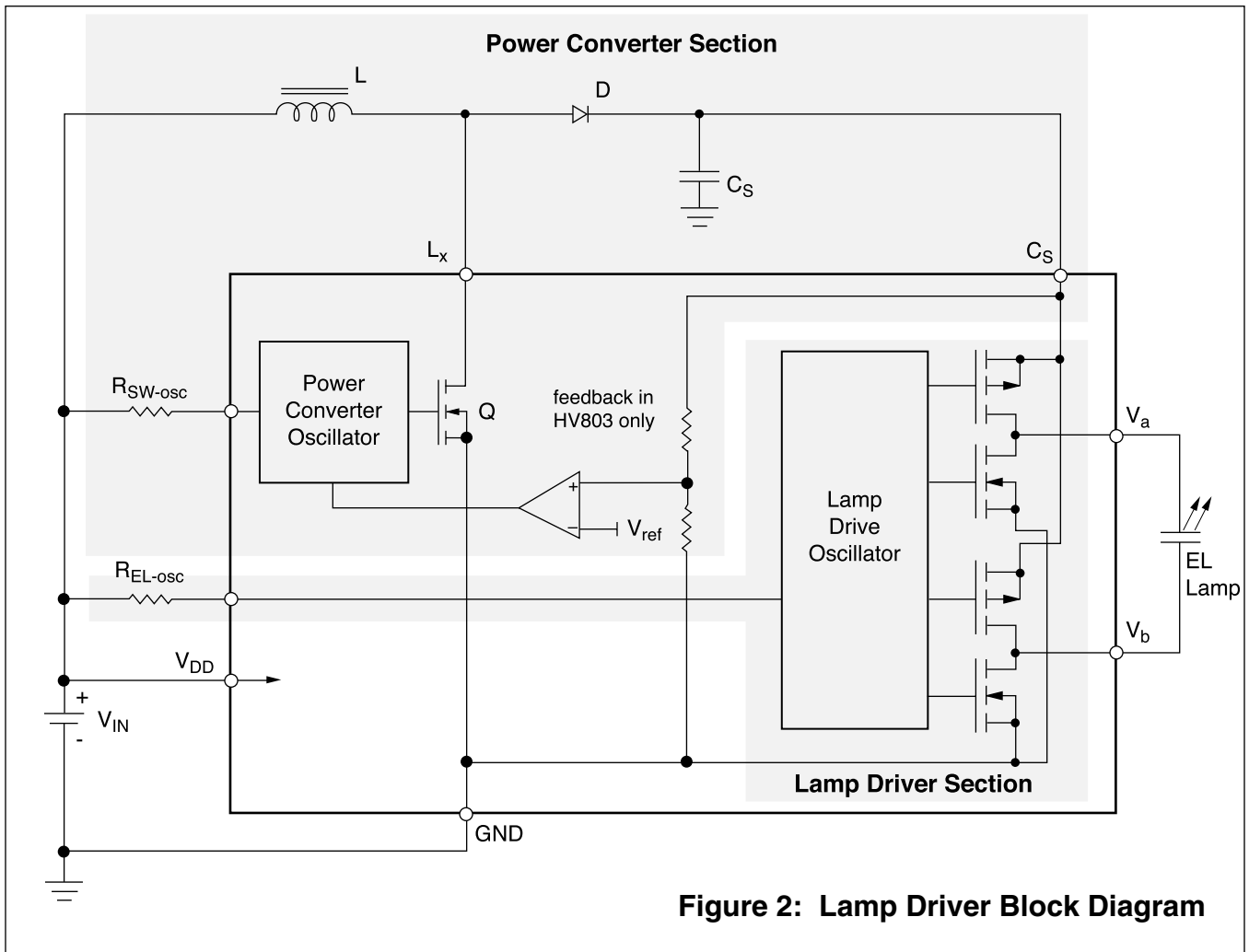|		
V_{IN}	=	supply voltage
V_{CS}	=	output voltage
R_{SW}	=	switch resistance
R_L	=	inductor resistance
L	=	inductance
f_c	=	conversion frequency
t_{ON}	=	switch ON time = (duty cycle) / f_c
t_d	=	inductor discharge time $\approx L\,\dfrac{I_L}{V_{CS} - V_{IN}}$
W_{RL}	=	energy lost to inductor resistance during discharge

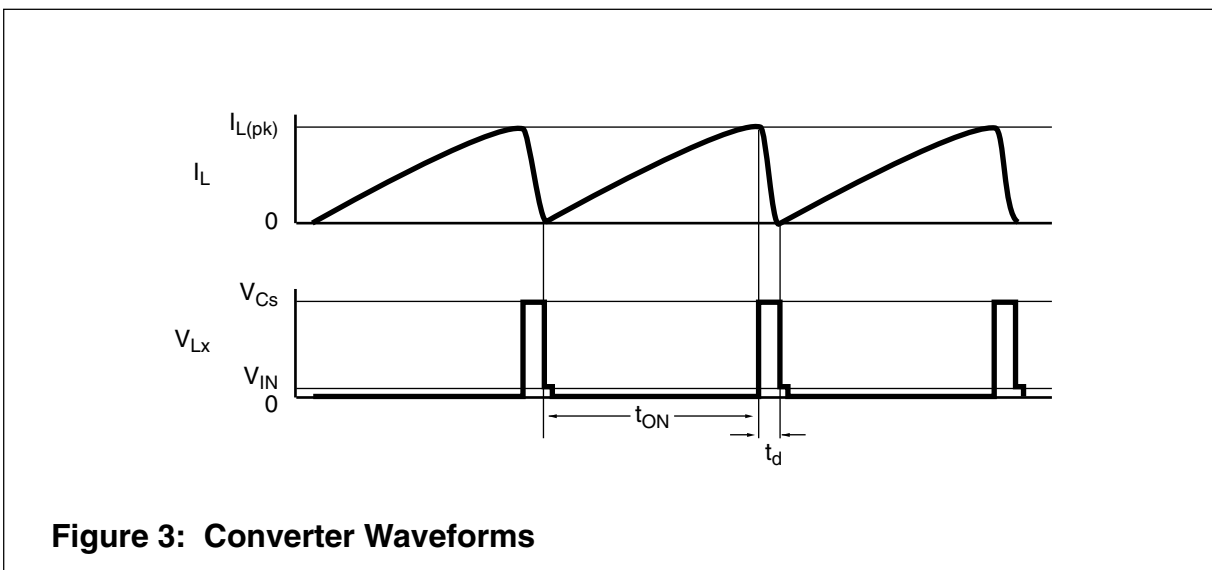Figure 2: Lamp Driver Block Diagram

Figure 3: Converter Waveforms

These equations are intended to illustrate the basic operation of the converter and do not take into account the effects of core loss, rectifier loss, parasitic capacitance, and various other circuit parameters.

With each conversion cycle, energy is transferred to C_s, raising its voltage until a stable operating voltage is achieved. This stable operating point is attained in one of two ways, depending on whether open loop conversion or closed loop regulation is employed.

In open-loop conversion, V_{CS} stabilizes when a balance is attained between the fixed amount of energy transferred to C_S and the amount consumed by the load. With loads such as EL lamps, energy consumed by the load increases with applied voltage, thus V_{CS} will rise until a balance is achieved between energy consumed and energy delivered. However, lamp capacitance (and thus brightness) can vary from lamp-to-lamp due to normal manufacturing variances. In addition, lamp capacitance and brightness decrease as a lamp ages. Less power is needed to drive lower capacitances, allowing V_{CS} to increase slightly. Since lamp brightness increases with higher voltages, a certain degree of compensation for lamp-to-lamp variances and lamp aging is offered by open loop drivers.

In closed loop regulation, V_{CS} stabilizes when voltage regulation circuitry monitoring the output voltage controls the conduction of Q. Closed loop regulation is generally not needed unless the supply voltage varies significantly. (Supply voltage determines the rate of current rise in the inductor and thus the amount of energy transferred to C_S and made available for driving the lamp.)

The HV8051 and HV8053 employ open loop conversion while the HV803 employs closed loop regulation. In the HV803, regulation occurs at 90 volts nominal, although the device may be operated open loop below this voltage.

Supertex drivers allow adjustable conversion frequency (via R_{SW-osc}), while duty cycle is fixed at a nominal 88% ON time. When designing a driver circuit, it is important to select the inductor and conversion frequency to provide the required output voltage while assuring that inductor current does not approach saturation levels. If the inductor saturates, excessive current will flow, potentially leading to device failure. Ideally, inductor current should be allowed to return to zero between cycles. If inductor current is not allowed to return to zero, a higher average current will be needed to meet output power requirements, increasing I^2R losses, and decreasing conversion efficiency. On the other hand, if too much time is allowed between zero inductor current and the start of the next cycle, more energy will need to be transferred each cycle to maintain output power, thus risking inductor saturation and increasing I^2R and core losses.

For most applications, inductors in the range of $100\mu H$ to $1mH$ are appropriate. As a general rule, larger inductor values and lower converter frequencies should be used for lower power applications. Refer to the Design Hints section for additional guidance

Lamp Driver Section

Supertex drivers incorporate a lamp drive oscillator that is separate from the power conversion oscillator. This allows setting lamp drive frequency independently from the power conversion frequency to optimize overall performance. The lamp drive oscillator is controlled by a single resistor, R_{EL-osc}.

The oscillator controls the lamp driver output section which consists of 4 transistors arranged in a bridge configuration as shown in Figure 2. Voltage (V_{CS}) is supplied by the power converter section. Alternate sets of output transistors are turned on by the drive oscillator, providing a lamp drive waveform as shown in Figure 4. This design has excellent drive capability and provides a symmetrical bipolar drive, resulting in a zero-bias signal. Many lamp manufacturers recommend a zero-bias drive signal to avoid potential migration problems and increase lamp life.

Figure 4: Lamp Drive Waveform
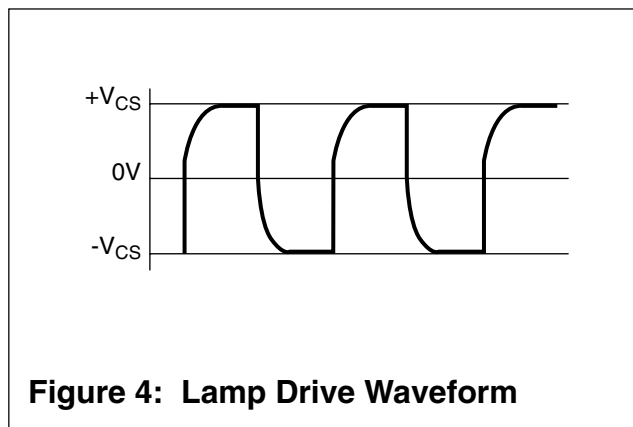
The design of the lamp driver section consists of selecting the value of R_{EL-osc} to produce the desired drive frequency. Increasing R_{EL-osc} decreases drive frequency. Typical values range from 1MΩ to 10MΩ.

A resistor in series with the lamp can extend drive capability for large lamps or for high brightness applications. Two different conditions, as described in the following paragraphs, may necessitate this: power dissipation or high V_{Cs} voltages.

The power consumed by charging and discharging the lamp's capacitance is given by $2f_{EL-osc}C_{LAMP}V_{Cs}^2$. This power is mainly dissipated in the bridge transistors during output transitions. With high lamp drive frequencies, large lamps, or high V_{Cs}, power dissipation can exceed specifications. A limiting resistor will absorb some of this power, while still allowing peak voltage excursions, thus extending the output capability of the driver. Depending upon application, values typically range from 1k to 10k ohms.

High V_{Cs} voltages may also necessitate a limiting resistor. When the bridge switches, the lamp (whose capacitance is charged to V_{Cs}) is in effect re-inserted into the bridge with a reverse polarity. Before the lamp charges to the new polarity, the bridge briefly experiences twice V_{Cs}, which can result in breakdown of the bridge transistors if V_{Cs} is high enough. A resistor in series with the lamp will absorb a portion of this voltage, avoiding transistor breakdown. A 2kΩ limiting resistor should be used if V_{Cs} is above 80 volts.

For very large lamps with their large capacitances, a FET follower circuit may be employed to boost the output drive capability of the lamp driver. Refer to Example Circuit 9 at the end of this application note.

Remote Enable

Remote enable is implemented by connecting R_{SW-osc} and R_{EL-osc} to a signal that swings between ground and V_{DD}. When the remote enable is at ground, the power conversion and lamp drive oscillators are halted and the driver becomes disabled. When the remote enable signal is at V_{DD}, the oscillators function normally and the driver is enabled.

Since R_{SW-osc} and R_{EL-osc} are typically high resistances, loading of the remote enable signal is minimal. However, to avoid interactions between the power conversion and lamp drive oscillators, the remote enable signal should be from a CMOS output of less than 20k ohms.

Refer to the Example Circuits at the end of this application note for several design examples.

Split Supplies

Some applications require a high lamp drive capability but operate from a 1.5 volt source. The HV803 provides high lamp drive, but does not operate from a 1.5 volt source. A technique using split supplies overcomes this limitation.

Many applications that operate from a 1.5 volt supply employ a voltage booster to provide a nominal 3 volts. Although this 3 volt low current supply usually cannot deliver enough power to drive an EL lamp, a split-supply driver circuit circumvents this obstacle. With this technique, the HV803 (which only requires 100μA maximum) is supplied by the 3 volt supply, while the inductor is fed from the 1.5 volt high current source. Example Circuit 2 provides a good design example.

Alternatively, this technique can be used to operate lamp drivers from supplies whose output voltage exceeds driver ratings. Refer to Example Circuits 3, 5, and 9.

Circuit Quick Reference

The following generic schematic and component table are provided as a convenient reference for designing and optimizing a lamp driver circuit. The choice of driver and of component values depends upon the particular application. Refer to the section on example circuits for additional guidance.
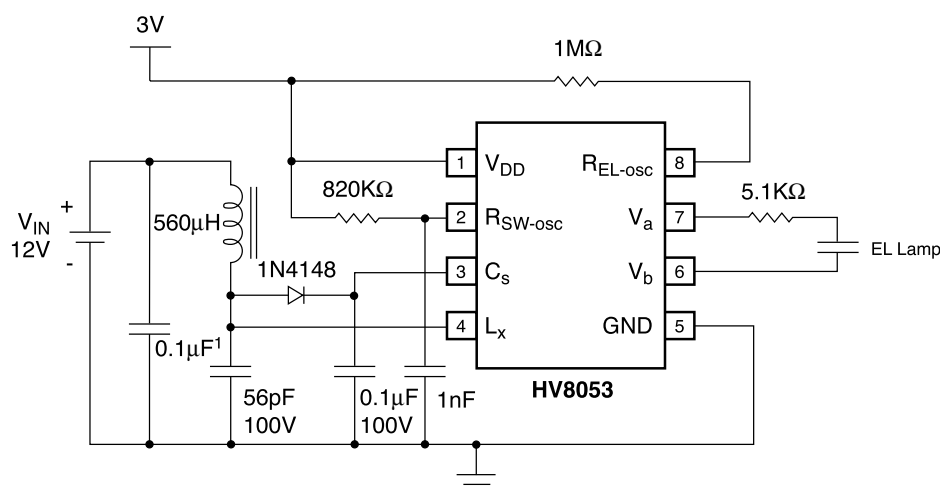

Figure 5: EL Lamp Driver Circuit

Notes:
1.   HV803 (tie to V_{DD} otherwise).
2,3. Required in certain instances.

Component	Function	Notes	Value	Rating
L	Generates high voltage using flyback	Use smaller inductors and higher conversion frequencies to increase output voltage.	$100\mu H$ to $1mH$	$1.2\mu J$ DCR $< 30\Omega$ $f_r > 1MHz$
D	Gates energy from inductor to C_s	Use fast recovery.	1N4148	100V 10mA
C_s	Stores high voltage energy	Use ceramic for low loss. Use smaller values for larger lamps.	10nF to 100nF	100V
R_{SW-osc}	Sets power conversion frequency	Lower values increase conversion frequency.	$560k\Omega$ to $1M\Omega$	1/16 W
R_{EL-osc}	Sets lamp drive frequency	Lower values increase drive frequency.	$1M\Omega$ to $10M\Omega$	1/16 W
C_{bp}	Eliminates noise at R_{SW-osc}	Only needed for supply voltages of 5V or above.	1nF	10V
C_{IN}	Supply bypass	Locate close to driver circuit.	$0.1\mu F$ to $1\mu F$	> supply voltage
R_{LIM}	Extends output drive capability	Not always needed - see Lamp Driver section.	$1k\Omega$ to $10k\Omega$	1/8 W

Design Hints

In keeping with good circuit design practice, the supply voltage should be bypassed with a capacitor located close to the lamp driver. Values can range from $0.1\mu F$ to $1\mu F$ depending on supply impedance.

At supply voltages above 5 volts, a 1nF capacitor is recommended from the R_{SW-osc} pin to ground to reduce noise.

For low power consumption, set a low lamp drive frequency, use a 1mH inductor, and adjust power conversion frequency for minimum current draw.

For high brightness, set lamp drive frequency for desired hue, use a $330\mu H$ inductor and adjust power conversion frequency appropriately.

For high lamp drive frequencies, employ a FET follower on the output. See Example Circuit 7.

For longer lamp life, use as low a lamp drive frequency as is acceptable. Adjust converter frequency and inductor value to obtain minimally acceptable brightness.

For wide supply voltage fluctuations, use the HV803.

Example Circuits

The following are examples of driver circuits optimized for various applications. These may be used as a starting point in designing a circuit for a particular application.

Circuit Selector Guide[1]

Application	Lamp Size/Color	Lamp[2,3] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency	Circuit
Pagers	1.25in² Green	4.5ft-lm	1.5V	25mA	130V$_{PP}$	500Hz	1
Pagers, (remote enable)Green	1.7in²	5.5ft-lm	1.5V/3.0V	45mA	127V$_{PP}$	400Hz	2
Travel Clocks, Wall Thermostats	1.25in² Green	3.5ft-lm	3.0V	30mA	114V$_{PP}$	500Hz	3
Pagers (low current)	1.5in² Green	3.6ft-lm	3.0V	10mA	129V$_{PP}$	260Hz	4
Phones, Automotive, Wall Mount Units	3.5in² Green	7.5ft-lm	12V/3.0V	25mA	180V$_{PP}$	800Hz	5
GPS Units, Cell Phones, Organizers	3.5in² Green	5.8ft-lm	3.3V	30mA	124V$_{PP}$	400Hz	6
GPS, Organizers	6.0in² Green	2.3ft-lm	3.3V	18mA	110V$_{PP}$	135Hz	7
GPS Units, Organizers RFDC Units, Handheld Scanners, Cell Phones, Clocks, Radios	8.0in² Green	5.7ft-lm	5.0V	50mA	160V$_{PP}$	400Hz	8
Instrument Panels, Keyboard Backlighting	9.0in² White[3]	3.0ft-lm	12V/5.0V	28mA	180V$_{PP}$	1KHz	9
PDA, HPC	10in² Green	3.1ft-lm	5.0V	25mA	125V$_{PP}$	260Hz	10
PDA, HPC	12in² Green	5.0ft-lm	3.3V	75mA	144V$_{PP}$	180Hz	11

Notes:
1. All values are nominal.
2. Lamp brightness can vary by type and manufacturer.
3. White lamps are inherently less efficient.

When constructing and testing one of the driver circuits listed above, keep in mind that results may differ from those given due to component tolerances and lamp characteristics. Use the Design Hints and Circuit Quick Reference sections to aid in adjusting component values to optimize the circuit.

The following are general guidelines for optimizing a driver circuit.

1. Select and construct an example circuit that closely matches your particular application and requirements.

2. Adjust converter frequency (via R_{SW-osc}) and inductor value* to obtain desired lamp drive voltage and supply current. Make sure that the inductor does not approach saturation as specified on the inductor data sheet. Adjust converter frequency and/or inductor value as necessary. If the desired V_{Cs} cannot be obtained, try decreasing lamp drive frequency slightly.

3. FOr the same value inductor with lower series resistance, faster switching frequency needs to be used. This is done by using smaller value R_{SW-osc}.

4. Adjust the value of R_{EL-osc} to obtain desired lamp drive frequency.

5. If V_{Cs} is above 80 volts, insert a 2kΩ resistor in series with the lamp.

6. Monitor overall power consumption. If it is above 350mW, insert a limiting resistor in series with the lamp to decrease device power dissipation.

When making circuit adjustments, always remove supply voltage first. After adjustments, bring up the supply voltage slowly while monitoring input current.

* Various brands/types of inductors may be used as long as provision is made for series resistances that differ from the recommended inductor.
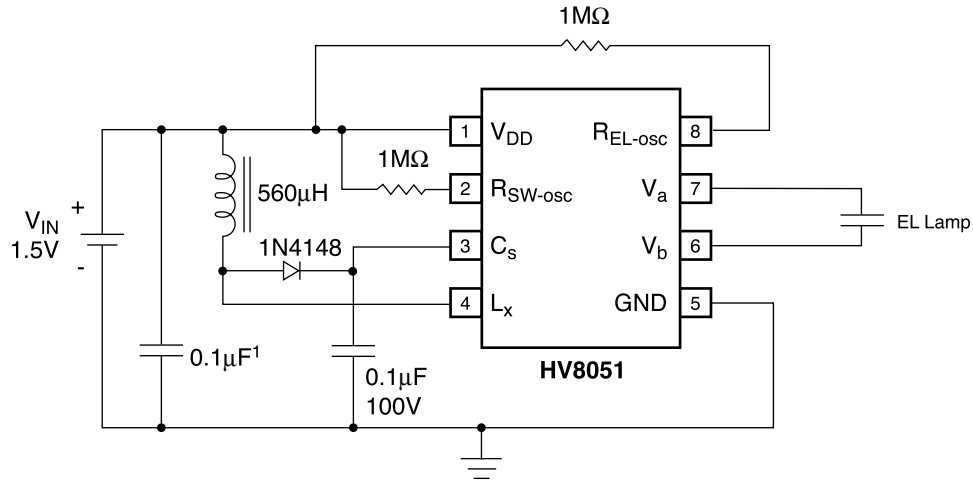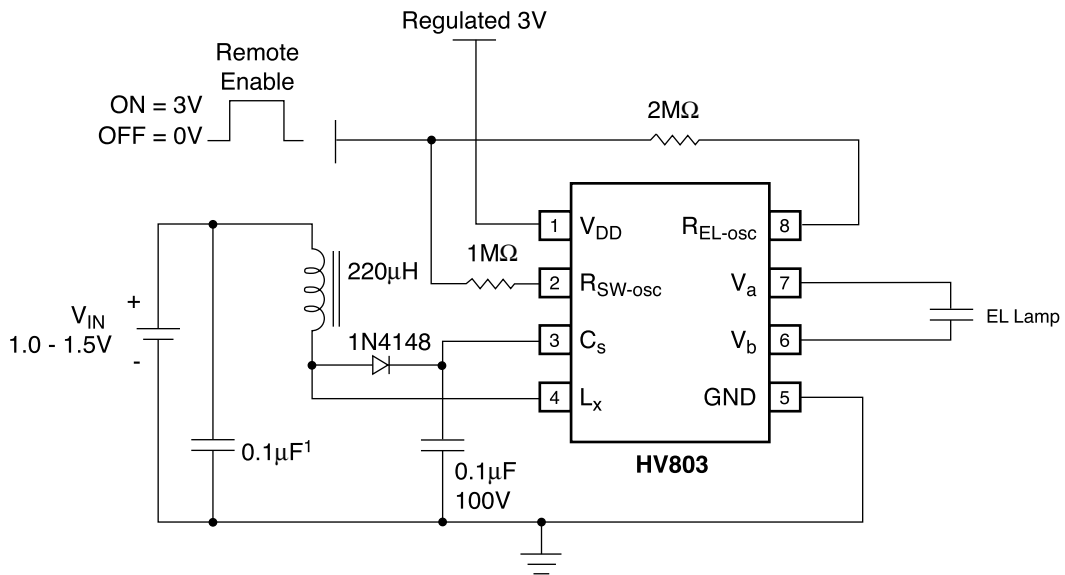
Circuit 1

Inductor: Murata LQH4N561

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
Pagers	1.25in^2 Green	4.5ft-lm	1.5V	25mA	130V$_{PP}$	500Hz

Note:
1. Larger values may be needed depending upon supply impedance.
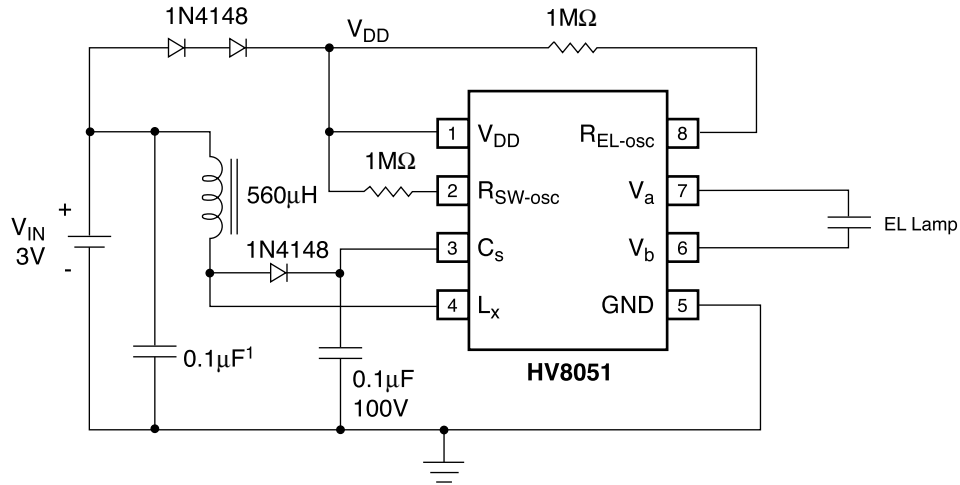2. Lamp brightness can vary by type and manufacturer.

Circuit 2

Inductor: Murata LQH4N221

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
Pagers, (remote enable)Green	1.7in^2	5.5ft-lm	1.5V/3V	45mA	127V$_{PP}$	400Hz

Note:
1. Larger values may be needed depending upon supply impedance.
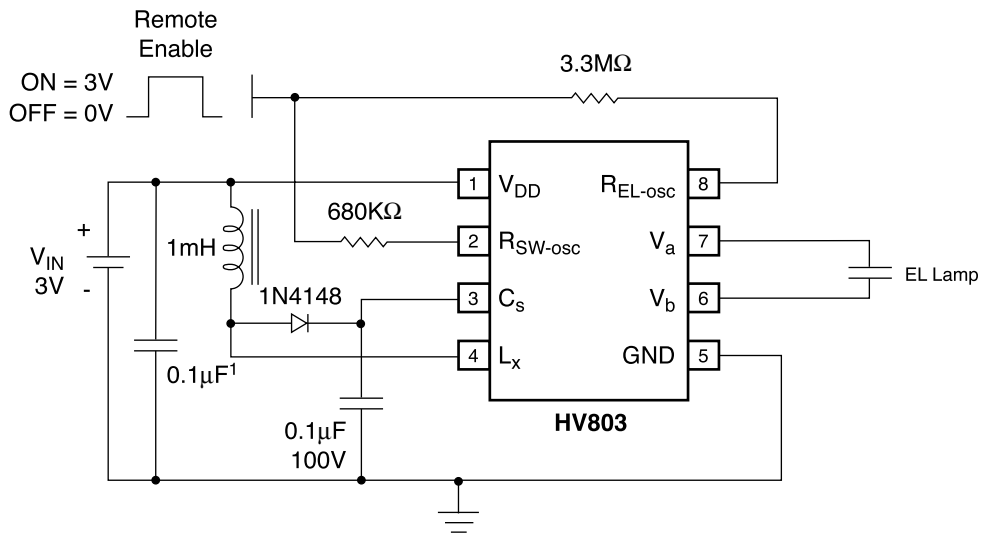2. Lamp brightness can vary by type and manufacturer.

Circuit 3

Inductor: Murata LQH4N561

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
Travel Clocks, Wall Thermostats	1.25in^2 Green	3.5ft-lm	3V	30mA	114V$_{PP}$	500Hz

Note:
1. Larger values may be needed depending upon supply impedance.
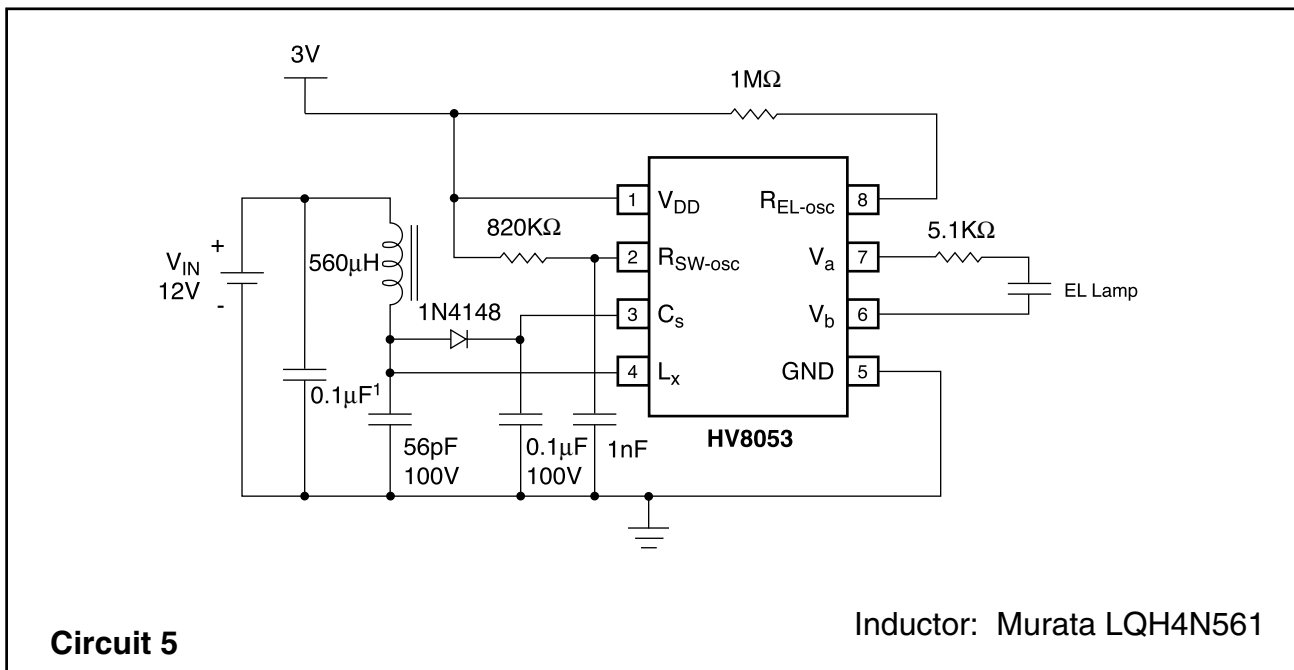2. Lamp brightness can vary by type and manufacturer.
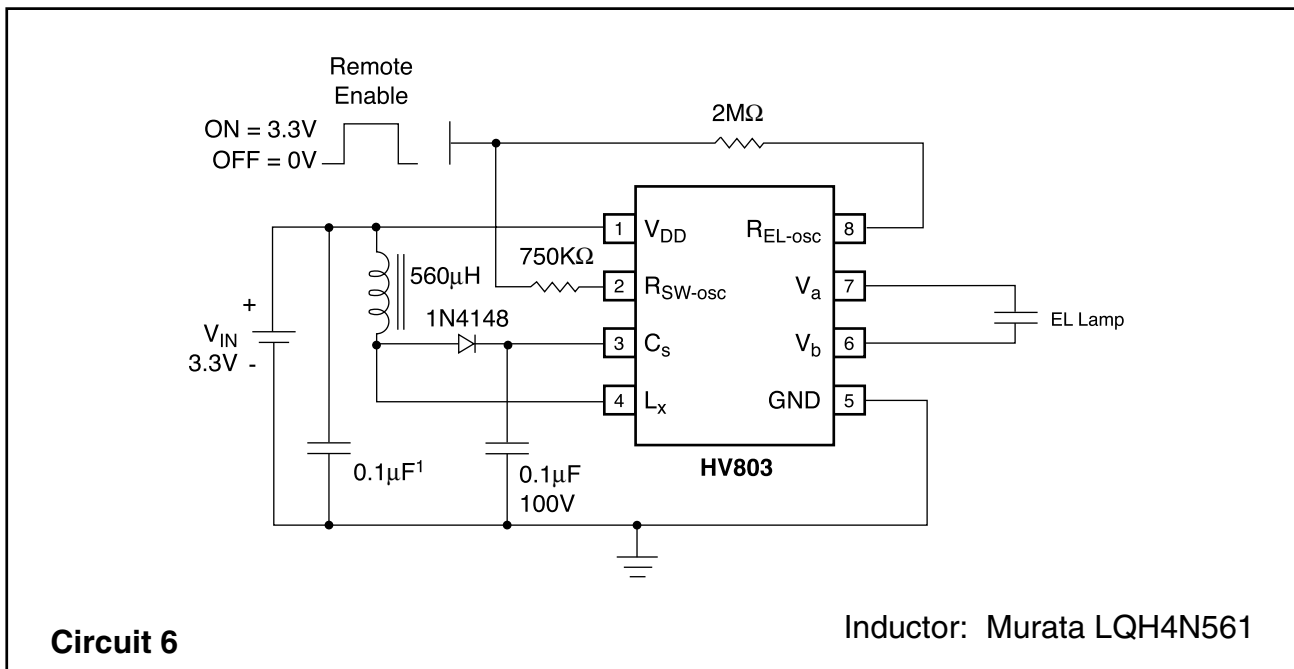

Circuit 4

Inductor: Murata LQH4N102

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
Pagers (low current)	1.5in^2 Green	3.6ft-lm	3.0V	10mA	129V$_{PP}$	260Hz

Note:
1. Larger values may be needed depending upon supply impedance.
2. Lamp brightness can vary by type and manufacturer.

Circuit 5

Inductor: Murata LQH4N561

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
Phones, Automotive, Wall Mount Units	3.5in^2 Green	7.5ft-lm	12V/3V	25mA	180V$_{PP}$	800Hz

Note:
1. Larger values may be needed depending upon supply impedance.
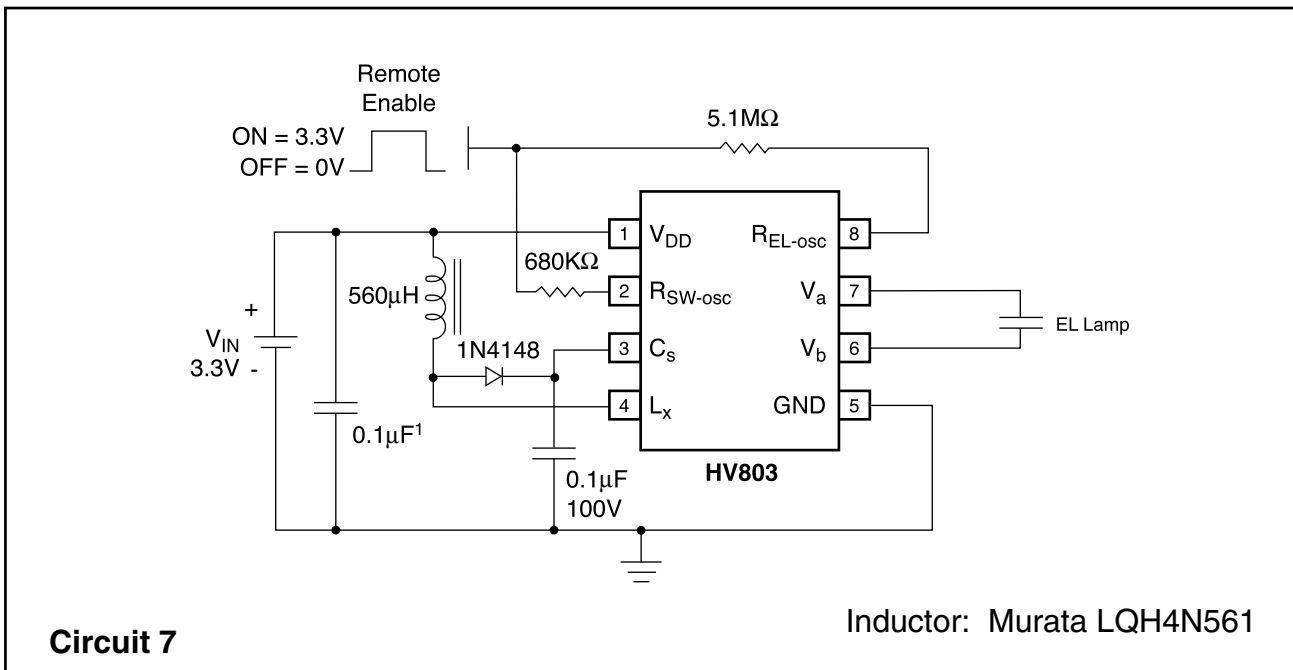2. Lamp brightness can vary by type and manufacturer.

Circuit 6

Inductor: Murata LQH4N561

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
GPS Units, Cell Phones, Organizers	3.5in^2 Green	5.8ft-lm	3.3V	30mA	124V$_{PP}$	400Hz

Note:
1. Larger values may be needed depending upon supply impedance.
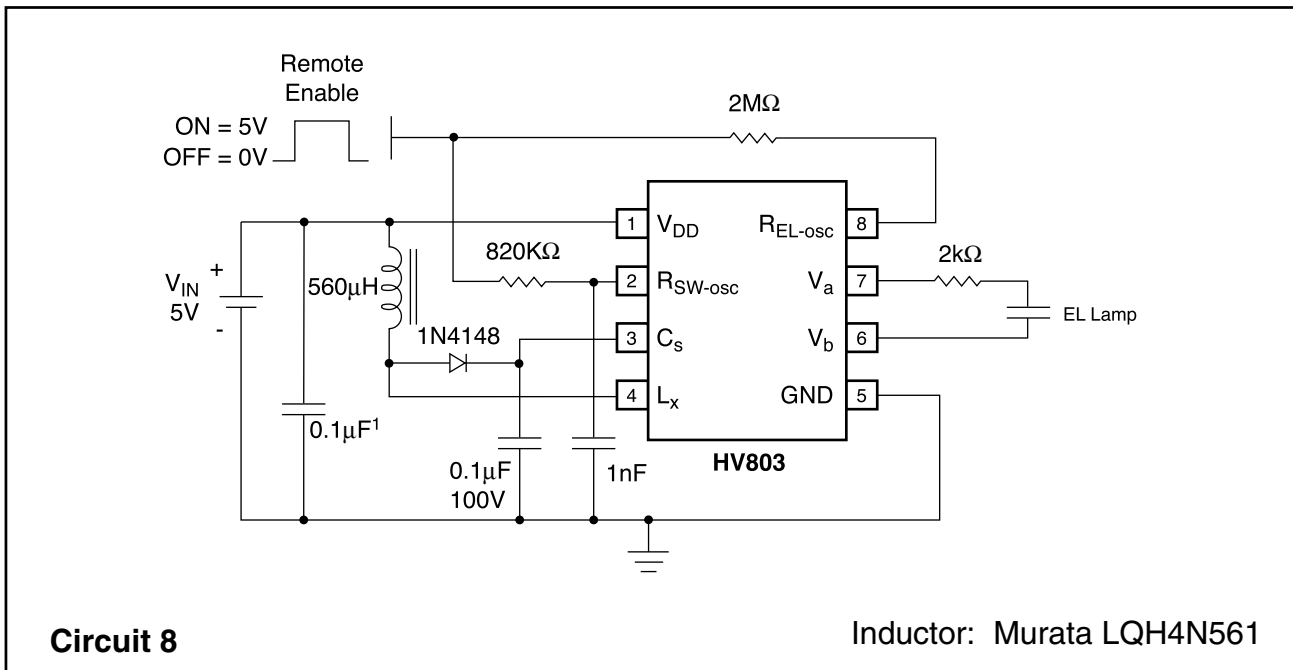2. Lamp brightness can vary by type and manufacturer.

Circuit 7

Inductor: Murata LQH4N561

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
GPS, Organizers	6in² Green	2.3ft-lm	3.3V	18mA	110V$_{PP}$	135Hz

Note:
1. Larger values may be needed depending upon supply impedance.
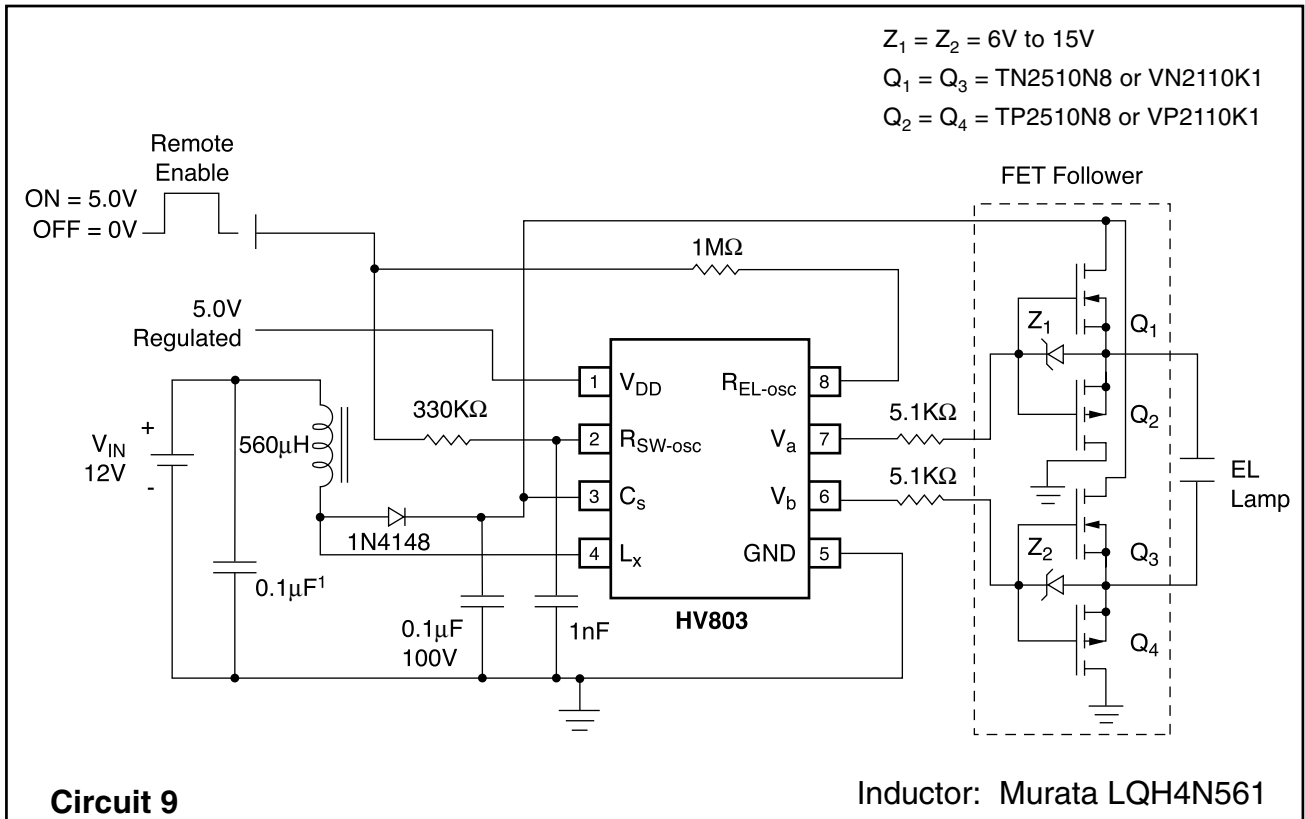2. Lamp brightness can vary by type and manufacturer.

Circuit 8

Inductor: Murata LQH4N561

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
GPS Units. Organizers, RFDC Units, Handheld Scanners, Cell Phones, Clocks, Radios	8in² Green	5.7ft-lm	5V	50mA	160V$_{PP}$	400Hz

Note:
1. Larger values may be needed depending upon supply impedance.
2. Lamp brightness can vary by type and manufacturer.

$Z_1 = Z_2 = 6V$ to $15V$

$Q_1 = Q_3 = TN2510N8$ or $VN2110K1$

$Q_2 = Q_4 = TP2510N8$ or $VP2110K1$

Circuit 9

Inductor: Murata LQH4N561

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
Instrument Panels, Keyboard Backlighting	9in^2 White	3.0ft-lm	12V/5V	28mA	180V$_{PP}$	1kHz

Note:
1. Larger values may be needed depending upon supply impedance.
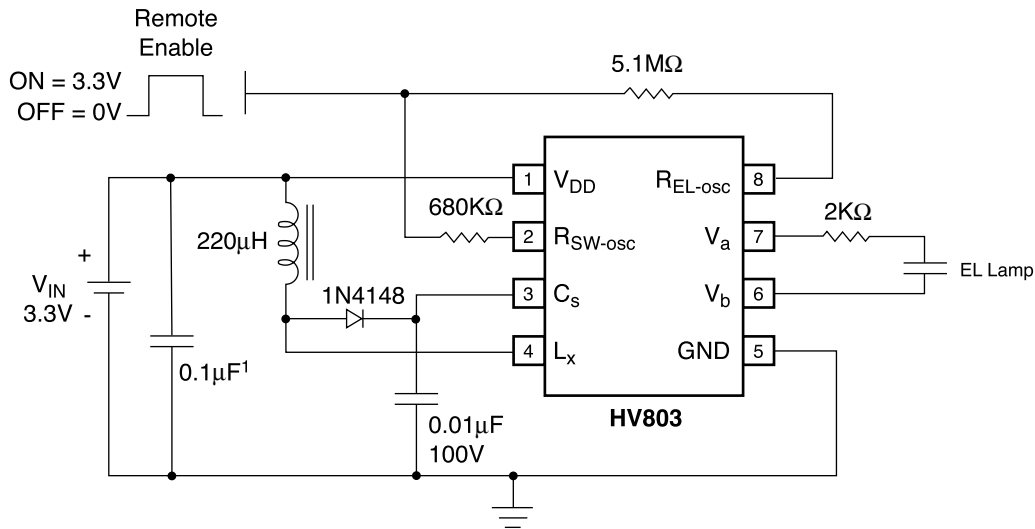2. Lamp brightness can vary by type and manufacturer.

Circuit 10

Inductor: Murata LQH4N102
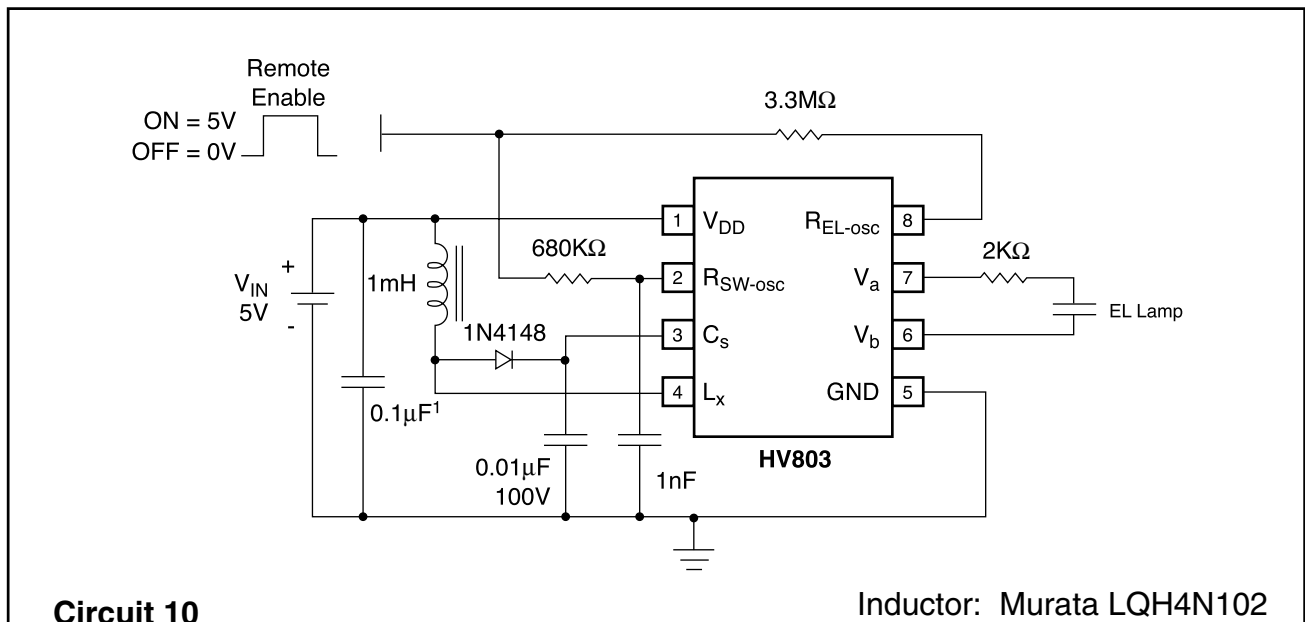
Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
PDA, HPC	10in^2 Green	3.1ft-lm	5.0V	25mA	125V$_{PP}$	260Hz

Note:
1. Larger values may be needed depending upon supply impedance.
2. Lamp brightness can vary by type and manufacturer.

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Circuit 11   Inductor: Murata LQH4N221

Application	Lamp Size/Color	Lamp[2] Brightness	Supply Voltage	Supply Current	Output Voltage	Output Frequency
PDA, HPC	12in^2 Green	5.0ft-lm	3.3V	75mA	144V$_{PP}$	180Hz

Note:
1. Larger values may be needed depending upon supply impedance.
2. Lamp brightness can vary by type and manufacturer.