

Low Voltage Electroluminescent Lamp Driver with Regulated Output Voltage

- +2.2V to +4.5V Battery Operation
- DC-to-AC Converter Produces 160V_{PP} typical for EL Display Panels
- Single Resistor Controlled Internal Oscillator
- Low Current Standby Mode
- Internal Feedback Loop Maintains a Constant Regulated EL Lamp Voltage Output

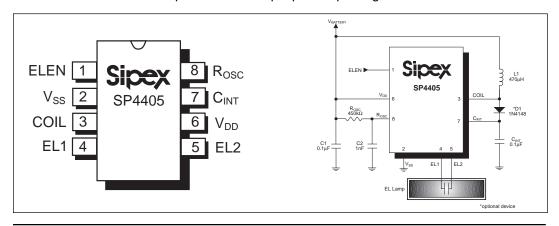
APPLICATIONS

- Pagers
- Cellular Phones
- PDAs



DESCRIPTION

The **SP4405** is a high voltage output DC-AC inverter specifically designed to drive electroluminescent lamps to backlight liquid crystal displays, keypads, and backlit readouts used in battery operated portable equipment. The **SP4405** will operate from a +2.2V to +4.5V battery source. The device features an internal feedback loop that regulates the lamp voltage output to $160V_{pp}$ (typical) with varying supply voltages to maintain constant EL lamp brightness over the life of the battery. The device also has a low power shutdown mode which draws less than 50nA (typical), ideal for low power portable products. One external inductor is required to generate the high voltage AC output. One external resistor is used to set the internal oscillator frequency. The **SP4405** is ideal for portable applications such as pagers, cellular phones, PDAs, and other portable applications using LCDs in dim or low light environments. The **SP4405** is offered in 8-pin SOIC and 8-pin μ SOIC packages.



ABSOLUTE MAXIMUM RATINGS

These are stress ratings only and functional operation of the device at these ratings or any other above those indicated in the operation sections of the specifications below is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

Power Supply, V _{BATTERY}	7.0V
Input Voltages, ELEN (pin 1)	0.5V to (V _{DD} +0.5V)
Lamp Outputs	200V _{BB}
Operating Temperature	
Storage Temperature	65°C to +150°C
Power Dissipation Per Package	
8-pin NSOIC (derate 6.14mW/°C above +70°C)500mW
8-pin uSOIC (derate 4.85mW/°C above +70°C)	390mW

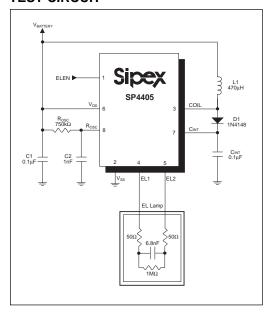
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SPECIFICATIONS

 $V_{BATTERY} = 3.0V, L = 470\mu\text{H}/3.9\Omega, \, R_{OSC} = 450\text{K}\Omega, \, C_{LAMP} = 6.8\text{nF}, \, T_{AMB} = 25^{\circ}\text{C} \, \, \text{and} \, \, C_{INT} = 0.1\mu\text{F} \, \, \text{unless otherwise noted; refer to test circuit.}$

PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITIONS	
Supply Voltage, V _{DD}	2.2	3.0	4.5	V		
Supply Current, I _{COIL} +I _{DD}		39 27	55 70	mA	V _{DD} =3.0V V _{DD} =4.5V	
Coil Voltage, V _{COIL}	V _{DD}		4.5	V		
ELEN Input Voltage, V _{ELEN} LOW: EL off HIGH: EL on	-0.25 V _{DD} -0.25	0 V _{DD}	0.25V V _{DD} +0.25	V		
Shutdown Current, I _{SD} =I _{COIL} +I _{DD}		0.1	1.0	μΑ	V _{DD} =4.5V	
INDUCTOR DRIVE						
Coil Frequency, f _{COIL} =f _{LAMP} x128		48.6		kHz		
Coil Duty Cycle		90		%		
Peak Coil Current, I _{PK-COIL}			60	mA	Guaranteed by design.	
EL LAMP OUTPUT						
EL Lamp Frequency, f _{LAMP}	320	380	500	Hz		
Peak to Peak Output Voltage	120 150	160	190 200	V _{PP}	V _{DD} =3.0V V _{DD} =4.5V	

TEST CIRCUIT



PIN ASSIGNMENTS

Pin 1 — ELEN — Eluminescent Lamp Enable. When driven HIGH, this input pin enables the EL driver output EL1 and EL2 (pins 4 and 5, respectively) to the EL lamp.

Pin 2 — V_{ss} — Power Supply Common. Connect to the lowest circuit potential, typically ground. Pin 3 — COIL — Coil. The inductor for the EL lamp is connected from V_{BATTERY} to this input pin.

Pin 4 — EL1 — Eluminescent Lamp. This is a lamp driver output pin to connect to the EL lamp.

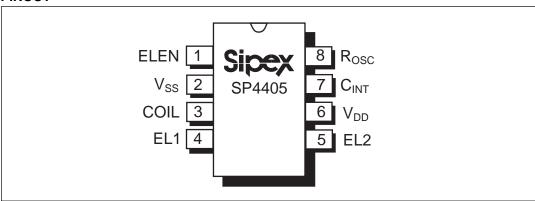
Pin 5 — EL2 — Eluminescent Lamp. This is a lamp driver output pin to connect to the EL lamp.

Pin 6 — V_{DD} — Positive Battery Power Supply. Connect such that $+2.2V < V_{DD} < +4.5V$.

Pin 7 — C_{INT} — Integrating Capacitor. Connecting a fast recovery diode from COIL (pin 3) to this input pin increases the light output of the EL lamp. An integrating capacitor (0.1μF) connected from this pin to ground filters out any coil switching spikes or ripple present in the output waveform to the EL lamp.

Pin 8 — $R_{\rm osc}$ — Oscillator Resistor. Connecting a 450k Ω resistor to this input pin sets the frequency of the internal clock.

PINOUT



DESCRIPTION

The **SP4405** Electroluminescent Lamp Driver is a low-cost low voltage device ideal for the replacement of LED backlighting designs in keypads, handsets, PDAs and other portable designs. The **SP4405** contains a DC-AC inverter that can produce an AC output of $160V_{\rm pp}$ (typical) from a +2.2V to +4.5V input voltage. An internal feedback loop regulates the lamp voltage output to $160V_{\rm pp}$ (typical) with varying supply voltages to maintain constant EL lamp brightness. An internal block diagram of the **SP4405** can be found in *Figure 1*.

The **SP4405** is built on **Sipex's** dielectrically isolated BiCMOS process that provides the isolation required to separate the high voltage AC signal used to drive the EL lamp from the low voltage logic and signal processing circuitry.

This ensures latch-up free operation in the interface between the low voltage CMOS circuitry and the high voltage bipolar circuitry.

A total of only six external components are required for the standard operation of the **SP4405**: an inductor, a fast recovery diode, three capacitors and a resistor. A diagram of the **SP4405** in a typical application can be found in *Figure 2*.

Electroluminescent Technology

An EL lamp is basically a strip of plastic that is coated with a phosphorous material which emits light (fluoresces) when a high voltage (>40V) which was first applied across it, is removed or reversed. Long periods of DC voltages applied to the material tend to breakdown the material

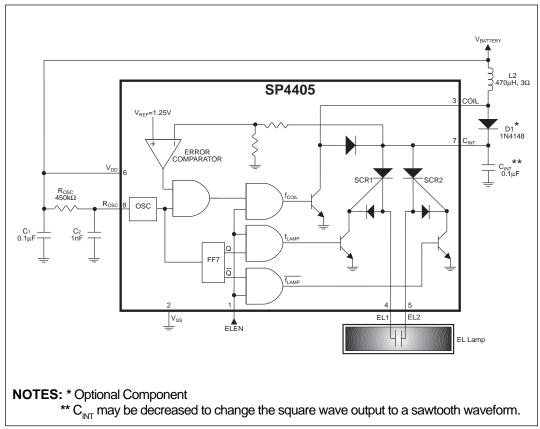


Figure 1. Internal Diagram of the SP4405

and reduce its lifetime. With these considerations in mind, the ideal signal to drive an EL lamp is a high voltage sine wave. Traditional approaches to achieving this type of waveform included discrete circuits incorporating a transformer, transistors, and several resistors and capacitors. This approach is large and bulky and can be difficult to implement in some smaller hand held equipment. **Sipex** now offers low power single chip driver circuits specifically designed to drive small to medium sized electroluminescent panels.

Market Applications

Electroluminescent backlighting is ideal when used with LCD displays, keypads, or other backlit readouts. Its main use is to illuminate displays in dim to dark conditions for momentary periods of time. EL lamps typically consume less power than LEDs or incandescent bulbs making them ideal for battery powered products. Also, EL lamps are able to evenly light an area without creating any undesirable "hot spots" in the display.

THEORY OF OPERATION

The **SP4405** is a DC-AC inverter made up of:
1. The Oscillator/Frequency Divider, 2. The Coil, and 3. The Switched H-bridge Network. Further details of each element follow.

The Oscillator/Frequency Divider

The oscillator provides the **SP4405** with an on-chip clock used to control the coil switch (f_{COIL}) and the H-bridge network (f_{LAMP}) and (f_{LAMP}) . Although the oscillator frequency can be varied to optimize the lamp output, the ratio of (f_{COIL}) (f_{LAMP}) will always equal 128.

Figure 1 shows the oscillator output driving the coil and the output of the oscillator with 7 flip flops driving the lamp. The suggested oscillator frequency is 48.6kHz ($R_{\rm OSC}$ = 450kΩ) for $f_{\rm COIL}$. The oscillator output is internally divided down by 7 flip flops to create a second internal control signal at 380Hz for $f_{\rm LAMP}$.

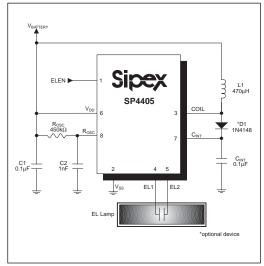


Figure 2. Typical Application Circuit for the SP4405, Set for a Square Wave Output with $C_{INT} = 0.1 \mu F$

The Coil

The supply $V_{\rm BATTERY}$ can range from +2.2V to +4.5V. $V_{\rm BATTERY}$ should be chosen such that $I_{\rm COIL}$ does not exceed the maximum coil current specification. The majority of the current goes through the coil and is typically much greater than $I_{\rm DD}$.

The coil is an external component connected from $V_{BATTERY}$ to pin 3 of the **SP4405**. Energy is stored in the coil according to the equation $E_{\rm L}=1/2LI_{\rm p}^2$ where $I_{\rm p}$, to the first approximation, is the product $I_P = (t_{ON}) (V_{BATTERY} - V_{CE})/L)$, where t_{ON} is the time it takes for the coil to reach its peak current, V_{CE} is the voltage drop across the internal NPN transistor for f_{COIL} , and L is the inductance of the coil. When the NPN transistor switch is off, the energy is forced through an internal diode which drives the switched H-bridge network. This energy recovery is directly related to the brightness of the EL lamp output. There are many variations among coils; magnetic material differences, winding differences and parasitic capacitances. For suggested coil suppliers, refer to Page 7.

The f_{COIL} signal controls a switch that connects the end of the coil at pin 3 to ground or to open circuit. The f_{COIL} signal is a 90% duty cycle signal switching at the oscillator frequency,

35kHz. During the time when the f_{COIL} signal is HIGH, the coil is connected from $V_{BATTERY}$ to ground and a charged magnetic field is created in the coil. When the f_{COIL} signal is LOW, the ground connection is switched open, the field collapses, and the energy in the inductor is forced to flow toward the high voltage H-bridge switches. f_{COIL} will send an array of charge pulses (see *Figure 4*) to the lamp. Each pulse increases the voltage drop across the lamp in discrete steps. As the voltage potential approaches its maximum, the steps become smaller (see *Figure 3*).

The Switched H-Bridge Network

The H-bridge consists of two SCR structures that act as high voltage switches. These two switches control the polarity of how the lamp is charged. The SCR switches are controlled by the f_{LAMP} signal which is the oscillator frequency divided by 128. For a 48.6kHz oscillator, the 7 flip flops will drive $f_{LAMP} = 380$ Hz.

When the energy from the coil is released, a high voltage spike is created triggering the SCR switches. The direction of current flow is determined by which SCR is enabled. One full cycle of the H-bridge will create 64 voltage steps from ground to 80V (typical) on EL1 and EL2 (pins 4 and 5, respectively) which are 180 degrees out of phase (see *Figure 5*). A differential representation of the output is shown in *Figure 6*.

The feedback loop connects the H-bridge network to the error comparator through an internal resistor network. When the error comparator senses a lamp voltage below regulation (< 80 V_p typical), the error comparator enables the oscillator to perform step-up conversions to the lamp output. When the error comparator senses lamp voltages above regulation (> 80 V_p typical), it disables the oscillator minimizing power consumption until the lamp voltage drops below regulation. With a varying supply voltage, the EL lamp brightness will appear constant as a direct result of this regulated output voltage.

Fine Tuning Performance

Circuit performance of the **SP4405** can be improved with some of the following suggestions:

Increase EL Lamp Light Output: By connecting a fast recovery diode from COIL (pin 3) to C_{INT} (pin 7), the internal diode of the switched H-bridge network is bypassed resulting in an increase in light output at the EL lamp. We suggest a fast recovery diode, such as the industry standard 1N4148, be used for D1. This circuit connection can be found in *Figure 2*.

Changing the EL Lamp Output Voltage Waveform: Designers can alter the sawtooth output voltage waveform to the EL Lamp. Increasing the capacitance of the integration capacitor C_{INT} will integrate the sawtooth waveform making it appear more like a square wave.

Printed Circuit Board Layout Suggestions:

The **SP4405**'s high-frequency operation makes PC layout important for minimizing ground bounce and noise. Keep the IC's GND pin and the ground leads of C1 and C_{INT} in Figure 2 less than 0.2in (5mm) apart. Also keep the connections to COIL (pin 3) as short as possible. To maximize output power and efficiency and minimize output ripple voltage, use a ground plane and solder the IC's V_{SS} (pin 2) directly to the ground plane.

EL Lamp Driver Design Challenges

There are many variables which can be optimized for specific applications. The amount of light emitted is a function of the voltage applied to the lamp by the inductor, the frequency at which it is applied, the lamp material and the lamp size. **Sipex** supplies characterization charts to aid the designer in selecting the optimum circuit configuration (see *Figures 7* to 25).

Sipex will perform customer application evaluations, using the customer's actual EL lamp to determine the optimum operating conditions for specific applications. For customers considering an EL backlighting solution for the first time, **Sipex** is able to offer retrofitted solutions to the customer's existing LED or non-backlit product for a thorough electrical and cosmetic evaluation. Please contact your local Sales Representative for **Sipex** or the **Sipex** factory directly to initiate this valued service.

Coil Manufacturers

Hitachi Metals Material Trading Division 2101 S. Arlington Heights Road, Suite 116 Arlington Heights, IL 60005-4142 Phone: 1-800-777-8343 Ext. 12 (847) 364-7200 Ext. 12

Fax: (847) 364-7279

Hitachi Metals Ltd. Europe Immernannstrasse 14-16, 40210 Dusseldorf, Germany Contact: Gary Loos Phone: 49-211-16009-0

Fax: 49-211-16009-29

Hitachi Metals Ltd. Kishimoto Bldg. 2-1, Marunouchi 2-chome, Chiyoda-Ku, Tokyo, Japan Contact: Mr. Noboru Abe

Phone: 3-3284-4936 Fax: 3-3287-1945

Hitachi Metals Ltd. Singapore 78 Shenton Way #12-01, Singapore 079120 Contact: Mr. Stan Kaiko Phone: 222-8077

Fax: 222-5232

Hitachi Metals Ltd. Hong Kong Room 1107, 11/F., West Wing, Tsim Sha. Tsui Center 66 Mody Road, Tsimshatsui East, Kowloon, Hong Kong Phone: 2724-4188 Fax: 2311-2095

Toko America Inc. 1250 Feehanville Drive Mt. Prospect, IL, 60056 U.S.A. Phone: (847) 297-0070

Fax: (847) 699-7864

Toko Inc. Europe Burgmullerstr. 7, D-40235 Dusseldorf 1, FR Germany Phone: (0211) 680090 Fax: (0211) 679-9567

Toko Inc. Japan 1-17, Higashi-Yukigaya 2-chome, Ohta-ku, Tokyo 145 Japan Phone: 03-3727-1161 Fax: 03-3727-1176

Toko Inc. Singapore No. 1 Lorong 2. Toa Pavoh. #03-00, Singapore, 319637 Phone: (255) 4000 Fax: (250) 8134

Toko Inc. Hong Kong 45 Hoi Yuen Road, Yau Lee Centre, 7th, 8th, & 9th Fl., Kwun-Tong Kowloon, Hong Kong

Phone: 2348131 Fax: 23419570

Sumida Electric Co., LTD. 5999, New Wilke Road, Suite #110

Rolling Meadows, IL, 60008 U.S.A. Fax: 011 88644252929 Phone: (847) 956-0666

Fax: (847) 956-0702

Sumida Electric Co., LTD. 4-8, Kanamachi 2-Chrome, Katsushika-ku, Tokyo 125 Japan Phone: 03-3607-5111

Fax: 03-3607-5144

Sumida Electric Co., LTD. Block 15, 996, Bendemeer Road #04-05 to 06, Singapore 339944 Republic of Singapore Phone: 2963388 Fax: 2963390

Sumida Electric Co., LTD. 14 Floor, Eastern Center, 1065 King's Road, Quarry Bay, Hong Kong

Phone: 28806688 Fax: 25659600

Murata 2200 Lake Park Drive, Smyrna Georgia 30080 U.S.A. Phone: (770) 436-1300 Fax: (770) 436-3030

Murata European Holbeinstrasse 21-23, 90441 Numberg, Postfachanschrift 90015 Phone: 011-4991166870

Fax: 011-49116687225

Murata Taiwan Electronics 225 Chung-Chin Road, Taichung, Taiwan, R.O.C. Phone: 011 88642914151

Murata Electronics Singapore 200 Yishun Ave. 7, Singapore 2776, Republic of Singapore Phone: 011 657584233 Fax: 011 657536181

Murata Hong Kong Room 709-712 Miramar Tower, 1 Kimberly Road, Tsimshatsui, Kowloon, Hong Kong Phone: 011-85223763898 Fax: 011-85223755655

Polarizers/transflector Mnfg.

Nitto Denko Yoshi Shinozuka Bayside Business Park 48500 Fremont, CA. 94538 Phone: 510 445 5400 Fax: 510 445-5480

Top Polarizer- NPF F1205DU Bottom - NPF F4225 or (F4205) P3 w/transflector

Transflector Material Astra Products Mark Bogin P.O. Box 479 Baldwin, NJ 11510 Phone (516)-223-7500 Fax (516)-868-2371

EL Lamp manufacturers

Leading Edge Ind. Inc. 11578 Encore Circle Minnetonka, MN 55343 Phone 1-800-845-6992

Midori Mark Ltd. 1-5 Komagata 2-Chome Taita-Ku 111-0043 Japan Phone: 81-03-3848-2011

Luminescent Systems Inc. (LSI) 4 Lucent Drive Lebanon, NH. 03766 Phone: (603) 643-7766 Fax: (603) 643-5947

NEC Corporation Yumi Saskai 7-1, Shiba 5 Chome, Minato-ku, Tokyo 108-01, Japan Phone: (03) 3798-9572 Fax: (03) 3798-6134

Seiko Precision Shuzo Abe 1-1, Taihei 4-Chome, Sumida-ku, Tokyo, 139 Japan Phone: (03) 5610-7089 Fax: (03) 5610-7177

Gunze Electronics 2113 Wells Branch Parkway Austin, TX 78728 Phone: (512) 752-1299 Fax: (512) 252-1181

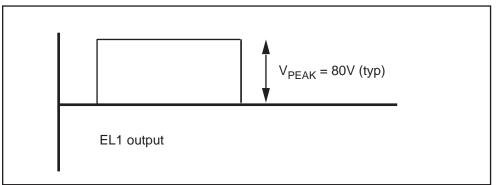


Figure 3. EL Output Voltage in Discrete Steps at EL1 Output

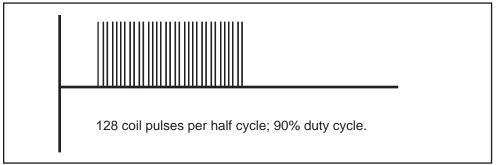


Figure 4. Voltage Pulses Released from the Coil to the EL Driver Circuitry

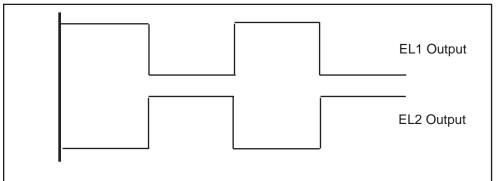


Figure 5. EL Voltage Waveforms from the EL1 and EL2 Outputs

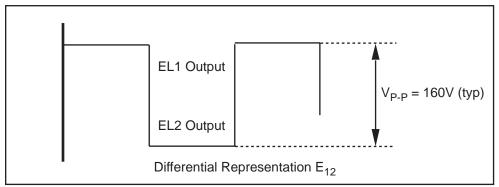


Figure 6. EL Differential Output Waveform of the EL1 and EL2 Outputs

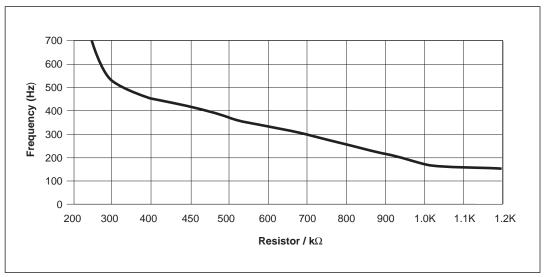


Figure 7. Lamp Frequency vs R_{osc}

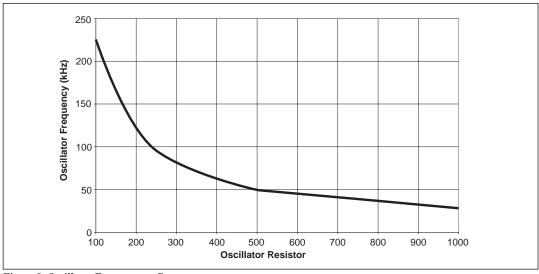


Figure 8. Oscillator Frequency vs R_{osc}

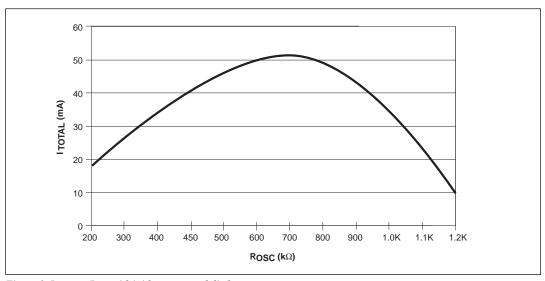


Figure 9. I_{TOTAL} vs R_{OSC} with/without external diode

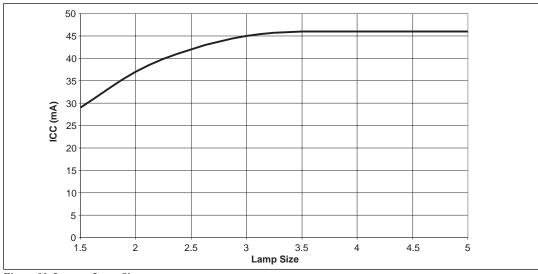


Figure 10. I_{TOTAL} vs Lamp Size

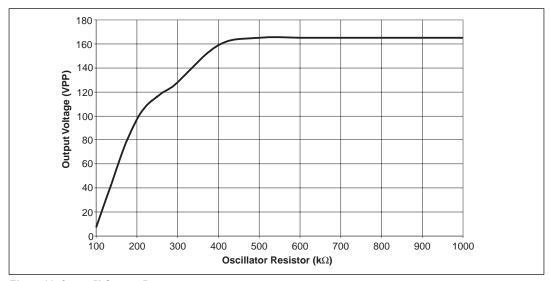


Figure 11. Output Voltage vs Rosc

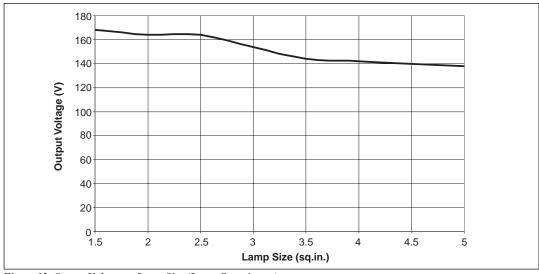


Figure 12. Output Voltage vs Lamp Size (Lamp Capacitance)

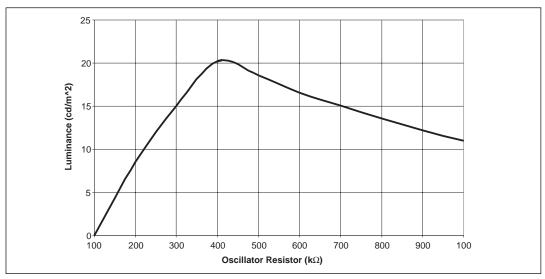


Figure 13. Luminance (cd/m²) vs R_{osc}

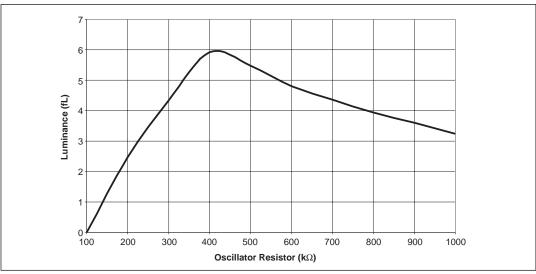


Figure 14. Luminance (fL) vs R_{osc}

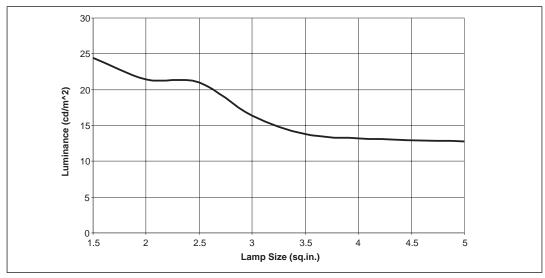


Figure 15.

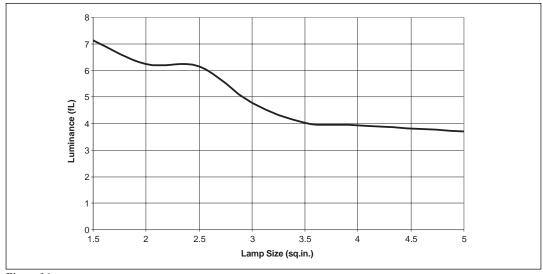


Figure 16.

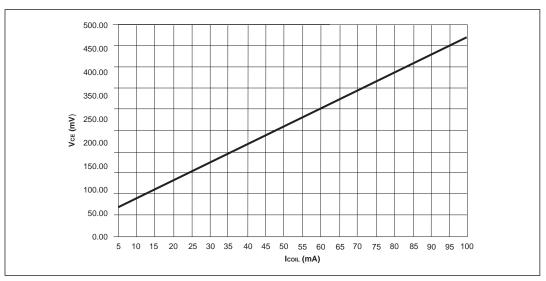


Figure 17. $V_{\rm CE}$ vs Coil Current

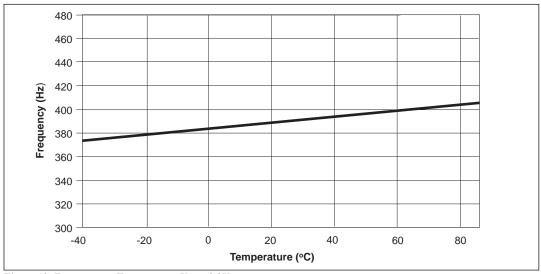


Figure 18. Frequency vs Temperature, $V_{DD} = 2.2V$

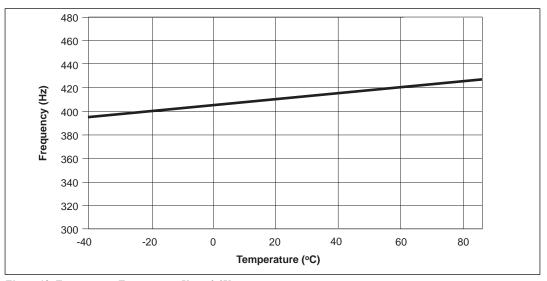


Figure 19. Frequency vs Temperature, $V_{\rm DD} = 3.0 V$

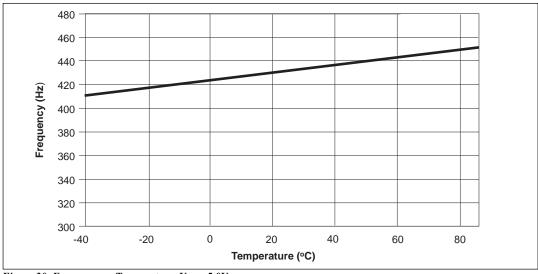


Figure 20. Frequency vs Temperature, $V_{DD} = 5.0V$

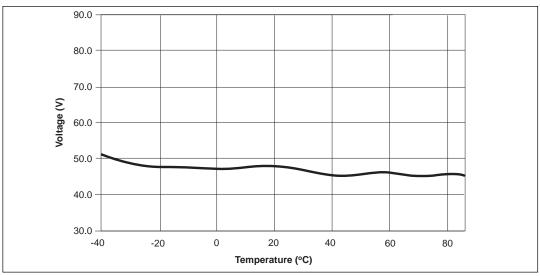


Figure 21. Peak EL Driver Voltage vs Temperature, $V_{\rm DD} = 2.2V$

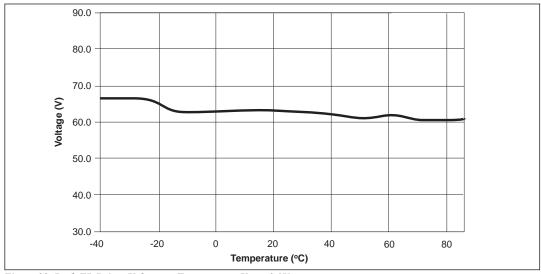


Figure 22. Peak EL Driver Voltage vs Temperature, $V_{DD} = 3.0V$

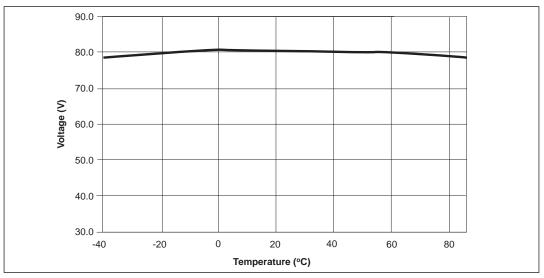


Figure 23. Peak EL Driver Voltage vs Temperature, $V_{\scriptscriptstyle DD}$ = 5.0V

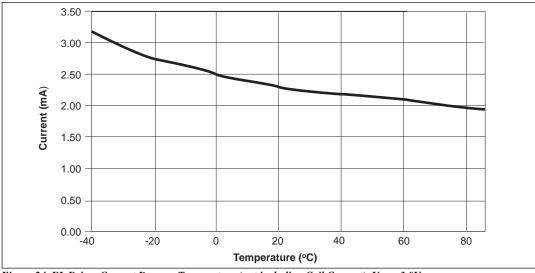


Figure 24. EL Driver Current Draw vs Temperature (not including Coil Current), $V_{DD} = 3.0V$

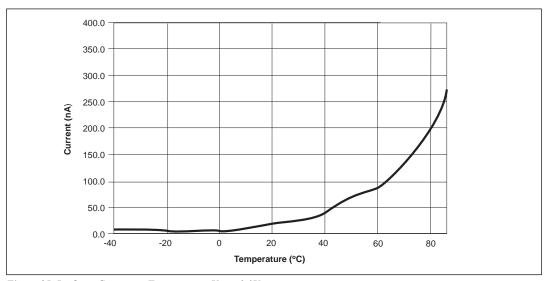


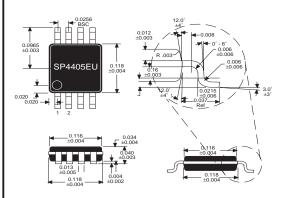
Figure 25. Leakage Current vs Temperature, $V_{DD} = 3.0V$

8-pin NSOIC 0.150/0.157 SP4405EN 0.228/0.244 0.053/0.069 1 0 die per waffle pack



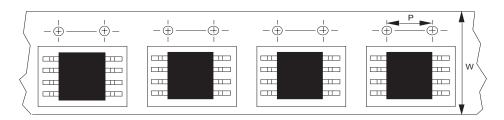
95 NSOIC devices per tube, no minimum quantity

8-pin μSOIC





50 μSOIC devices per tube



8-pin NSOIC 13" reels: P = 8mm, W = 12mm 8-pin μSOIC 13" reels: P = 8mm, W = 12mm					
Pkg.	min qty per reel	std qty per reel	max qty per reel		
EN EU	500 500	2500 2500	3000 3000		

ORDERING INFORMATION

Model SP4405EN	Temperature Range	Package Type
	40°C to +85°C	
SP4405NEB	N/A	Evaluation Board
SP4405UEB	N/A	Evaluation Board

Please consult the factory for pricing and availability on a Tape-On-Reel option.



SIGNAL PROCESSING EXCELLENCE

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