Final Report
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NIST Energy Related Inventions
Electronic Starter Device for Fluorescent Lamps

DE-FG01-97EE15656

ERIP # 656

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Applicant: Beacon Light Products, Inc. Ron Porter

Summary:

Due to silicon supplier failures to produce the 03/04 triac silicon as specified in the original proposal, the direction of the starter program was migrated to use available off the shelf power semiconductors. This had unexpected positive side effects including a reduction in component price, improved quality, and the re-focus of engineering efforts to concentrate on the Super ASIC core technology. The starter program has begun shipments employing this new architecture, and is being well received both in the US and abroad. In its present form, the starter meets our original cost projections within 20%. Work is continuing on the 0.8 micron ASIC, which will allow for the starter to sell below \$1.00 in volume. Even at the slightly higher price, interest is strong in replacing the low performance glow starter for small fluorescent applications with a high performance alternative.

Scope of work Projects:

Power Semiconductor Device:

The 03/04 custom silicon solution was not successful due to supplier quality problems. Instead, contact was established with Power Innovations, a UK spin-off of Texas Instruments. They have agreed to supply devices in wafer form which meet our specification. Thus, the large cost of associated packaging is avoided. Our present price is \$.13 each, which is better than the predicted pricing of the 03/04 combination. However, additional interface circuits are necessary with this approach until the Super ASIC is received back from fabrication.

Substrate layout/verification:

The ceramic substrate (printed circuit board equivalent), has been completed for a range of lamps, ballasts, and operating voltage. Part numbers have been assigned, and UL approval is in progress. The listing for US markets is as follows:

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	Lamp Type	Ballast Type	
QSM 11287	13-28W 60V Lamps	Reactance	
QSM 11305	8-280W 60V lamps	Reactance	
QSM 11305	13-40W 100V CFL and Linear lamps	AutoXmfr	
QSM	22W Circleline	Reactance	

For each of the products, only minor passive component changes are required to tailor the performance to a general range of lamps. Particular attention has been paid to maintaining the cathode life, which adds a few extra part numbers. This feature is valued by the ballast and fixture community as a selling advantage. These product are being sampled to customers currently, and form the basis for product already being shipped to overseas customers.

Super ASIC Development efforts:

Most of the engineering efforts were concentrated in this area by Mssrs. Zimmerman and Miller. Both are senior ASIC design engineers. The objectives were to engineer a much lower cost, higher performance ASIC than previous versions, thus the code name Super ASIC. This effort is 90% complete, with expected data base tape-out by 7/15/98.

The results of an interim silicon tape-out in the April time frame were successful. There, the prior silicon ("FSM-BAC" designation), was modified to remove a small quantity of external components, and to adjust the ASIC parameters to further improve lamp life. This intermediate silicon is named "FSM-BAH" The result showed an increase in lamp life during short duration burns of 700% for selected lamps. The number of lamp starts went from 50,000 to over 350,000. This was measured with statistically valid sample sizes on difficult to ignite lamps. Our customer also verified this result. Based on this study, and others like it, the functional performance characteristics of the existing ASIC were locked in. The FSM-BAH ASIC is currently in production.

The new Super ASIC will achieve the following performance:

Feature Set:

- Direct replacement for glow starters
- Wide range of applicability 8-40W demonstrated to 125 watt achievable
- Temp range -20 °C to + 125 °C
- Wide tolerance in supply voltage range > 20%
- World-wide mains voltage compatibility.
- Autotransformer, reactance, or energy saving magnetic ballast compatible.

Smart Start:

- Programmable phase delay firing angle.
- Programmable pre-heating period.
- Active snubbing for no flicker starts and reduced lamp blackening and long life.
- High tolerance to line induced noise.
- Greatly reduced light output loss over time due to micro-controlled ignition energy and timing.
- Extended lamp life due to smooth and flicker free ignition,
 - >100,000 start cycles 10 year start life at 1 start/hr.
 - >14,000 hours lamp operation (6.5 years at 6 hours/day)
- Aged lamp ignition further extends lamp life.
 - Multiple pulse striking capability with robust high voltage pulses.
- Failed lamp automatic safety shutdown.
 - Eliminates dead lamp flickering and need for immediate maintenance.
- High voltage (1400V) reduced temperature sensitivity ignition using the FL200B GTO mode with current sense.
- Asymmetric Quick Start- typically 1/3 of a second.
- Symmetric start option with programmable warm up time.
- Compatible with RFI condenser to meet RFI standards.
- Compatible with Power Factor Capacitor to meet PF standards > .90
- Inherent high reliability at high temperatures of the electronic power elements.
- Expandable functionality for dimming options at a later time.
- Very cost competitive.

A few of the above features are elaborated below:

Improvement of starting characteristics:

Prior implementations would apply preheating current to the cathodes for a prescribed time period which was pre-programmed into the ASIC. At the end of the preheat time period, the ASIC would wait for two AC cycles while it performed a lamp lit check. If the results of checking for the lamp lit were

negative, the ASIC would re-try for the same fixed pre-heat period. For a hard to ignite lamp, or low line voltage conditions, or a weak ballast design, the lamp lighting process of preheat, check, and re-heat can extend into durations which are perceptible by the user. If this time extended beyond 0.6 second, certain users perceived this to be a deficiency in the technology. Therefore, a preheat algorithm was developed which eliminates the preheat flicker and provides for a smoother ignition sequence. The basis of this new approach is presented in the flow chart of Attachment -A-, page 1. After an initial fixed preheat sequence of 1/8, 1/4, or 1/2 second (depending on the manufacturing coding), the ASIC will check each and every half cycle until 3 consecutive negative lamp lit detects are achieved. This provides for a very smooth, flicker free start. If the lamp does not ignite after 2 seconds, then the ASIC can pause and take other measures, as noted below.

Improved source voltage toleration:

For many areas of the world, voltage fluctuations are common, and can be severe. Even in the US, power quality is still a concern in rural areas and geographic locations such as the South, due to weather induced brown-outs. The QSM has been improved in this regard. If the lamp cannot be lit, or has extinguished due to a power sag or dropout, the ASIC will pause operations for 5 seconds, retry, and if still unsuccessful, the unit will shut down. This is a significant improvement over other starters in the market, which will lock up or self-destruct upon failure to ignite the lamp.

Improved operation in noisy circuits:

Often electrical wiring can pick-up stray voltages and currents from adjacent wiring or due to devices such as building automation systems, illuminated toggle switches, etc. We have learned that even when the power is off, voltage and current can be present in low levels. This leakage current can fool electronic systems into thinking power is applied, which can cause improper operation. While we have produced an external fix to the existing products which increases power consumption, a better solution to this problem is engineered into the ASIC. A novel approach of checking the impressed line voltage during a narrow time slice, and improving the on board voltage references, will guarantee that the QSM will operate in the worst noise environments as specified by our customers. This will expand the application of this technology into high noise environments, such as factories, commercial buildings, and even some residential applications.

Improved operation of low wattage lamps:

Significant interest in the operation of 8 watt and 13 watt linear lamps for undercabinet lighting forced us to implement a design which can operate very low current lamps also. Previous designs were specified only to 13 watts. By employing four added small components, we are now able to operate F8T5 lamps. The technology used to implement this is termed Current Sense, which

has the advantage of keeping the SCR device latched into full conduction even with small preheat currents. Another advantage with Current Sense is the ability to program the SCR holding current, which in turn produces the high voltage ignition pulse. Certain lamps, such as a 40W T8, can require higher holding currents when operated cold. Current Sense is a means to further tailor the performance of the module to the specific application. The Current Sense option is presently configured for the 8-28W product only.

Circuit Protection Technology:

Protective fusing of the device is required by several of our foreign customers. This is due in part to the lack of protective devices integrated into their ballast construction, as is required in the US to meet UL standards. Thus, QSM product sold for export has a discrete thermal acting fuse and a current sensing resistor installed in lieu of the two leads of the device. These are then overmolded with a UL rated epoxy potting system. Testing is performed to meet IEC 926 and 927 international standards.

Description of Design Elements:

Appendix -A- page 2

Mechanical Layout.

The elimination of components allows for a reduction in substrate size, as illustrated on this mechanical drawing. For comparison purposes, a postage stamp measures 7/8" x 1". Six of these QSM starter modules will fit in the stamp area. This is made possible by the use of ceramic chip and wire technologies, coupled with the extreme integration of functions of the Super ASIC.

Appendix -A- page 3

Electrical Schematic:

The Super ASIC design only requires 8 components to implement a starter only function. (Room is left for an optional R5 component). Since the resistor components (4) represent less than \$.01 cost, and diode components (1) is \$.02, the major cost of the system can be seen to be the silicon (PS3_BAA), Q1, and the mounting substrate.

Appendix -A- page 4

This shows the complete hook-up in the lamp and ballast system. It is intended that the placement of the starter will retrofit into all locations where there is presently a glow bottle. As high volume designs are won, we anticipate manufacturing the shape of the QSM to be dimensionally equivalent to a glow starter, thus fitting existing factory lamp automation processes.

Cost Objectives:

From the outset, it has been realized for this technology to gain acceptance, it's cost must approach that of the glow bottle it is designed to replace.

The following is a summary of actual costs and cost goals with the Super ASIC.

	Pre NIST Grant	Achieved during Grant Period	Super ASIC
Direct Material	2.05	.91	.63
Labor/Overhead	.85	.15	.12
Sales/Marketing	.25	.25	
Profit	.69	.10	.25
Final Product Cost	\$2.99	\$1.40	\$1.00

Summary:

Although the Super ASIC was not achieved on schedule, it's predicted release to the fabrication house by July 15, 1998 is very encouraging. Delaying it's release were several technical improvements which needed to be incorporated into the design. Many of these were based on customer feedback, and thus reflect the customers desire to see the technology evolve and improve. We feel this was the correct approach. Also encouraging is the ability to produce and sell this high level of technology for \$1.00 US. This aggressive pricing should hasten the acceptance of low cost fluorescent technology over inefficient incandescent and halogen types. The impact on energy consumption can be very significant, especially as there become fewer and fewer objections to the limitations and costs of fluorescent technology.

Acknowledgments:

The many engineers, managers, and employees of Beacon Light products are to be commended for their excellent effort to achieve this difficult goal. An especial thanks go to ASIC designers Gerry Miller and Randy Zimmerman for the tedious long hours of performing simulations and chip layout... to Engineers Dan Rothenbuhler, Tyler Lowrey, and Ward Parkinson for contributing systems level performance goals, to Test Engineers Rudy Hausdorf and Dennis Bradshaw for testing and performing long device characterizations, and to the fine manufacturing organization headed by Ron Porter who made it happen. Thyristor device simulations were performed by Rich Nelson and Dr. Lowell Clark, with assistance from Arizona State University and Northern Arizona University. This work was performed under DOE grant DE-FG01-97EE15656 ERIP # 656, to whom we are indebted.

PS3_BAA Heating Scenario, Flow Chart

BENCOR
 LIGHT PRODUCTS INC.

Description: LAYOUT
 Part#: SIMP1
 File: LSIMP1
 Engineer: DRB
 Latest Revision: 01-30-98

BENCOR
LIGHT PRODUCTS INC.

Description: SCHMETIC
Part#: MOD_SIMP.1
File: ZMODSIMP1.DWG
Engineer: GM
Latest Revision: 01-30-98

Fluorescent Simple Starter Module.

MOD_SMP.1

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Bond options

Id0, Id1 select 8 heat FA's and a 9th FA that steps through the above 8.

Id2 selects high I_h time.

Note that internal variable BRIDGE is false.