

Synchronizing Fireflies

by [alex_weber](#) on April 6, 2007

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Intro: Synchronizing Fireflies

Have you ever asked yourself how do hundreds and thousands of fireflies are able to synchronize themselves? How does it work, that they are able to blink all together without having a kind of boss firefly?

This instructable gives a solution and shows how this synchronization can be achieved.

I have always been fascinated by self organization of insects. A couple of years ago I wrote a Java-Applet that simulates a square of thousands of fireflies. It worked well and was fun to watch. This time I have done it in hardware.

Credits for inspirations goes to Keso and his Jar of fireflies <http://www.instructables.com/id/E7U5HYMSVIEWP86SAL/>.

Any comments or corrections are welcome.

Update 2008-09-12 : There is a new version of the fireflies online at [Synchronizing Firefly Howto](#) . It has a custom PCB for every firefly. And you can buy a kit at the [Tinker Store](#) .

Here is the video:

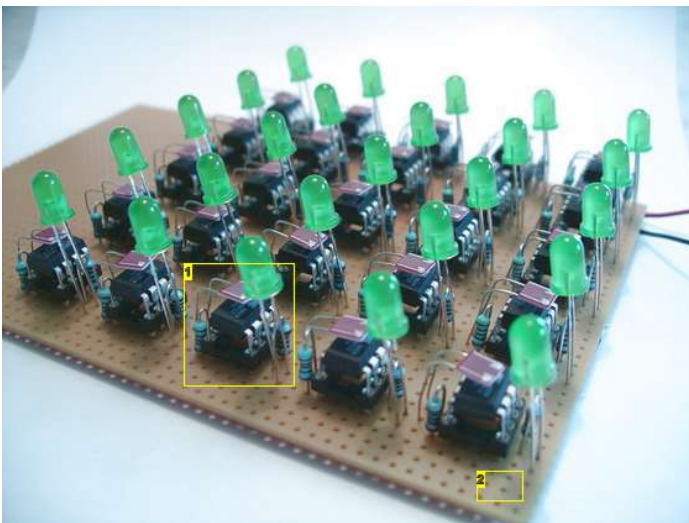


Image Notes

1. A single firefly.
2. THIS is a multi core.

Step 1: How it works

The algorithm

What can be observed is that the fireflies start with random blinking. But as time goes by, they are able to slowly synchronize with their nearest neighbors. And these neighbors are synchronizing themselves with their neighbors and so on and so on. Until the whole tree or the whole valley blinks in the same cycle.

And what is it good for? It is used to attract other specimen. With all the blinking in sync it is much easier to find a partner.

One of the easiest algorithm to explain this behaviour goes like this: You have a value that holds the power to flash. As time passes this power will slightly raise. If the power reaches a certain level, the firefly flashes and the power is consumed. The rate at which the power raises is nearly the same for all fireflies. So they have the same frequency but not the same point in time to flash.

While slowly charging with power the firefly is able to detect a flash of another firefly nearby. It adds then a higher value to its power value. Some kind of power boost, if you wish. That means the next flash will occur earlier than the one before. And next one even earlier, until these two are flashing exactly at the same point in time and with the same speed.

You can find more on this algorithm e.g. here:
[Firefly Synchronization Ad Hoc Networks](#)

The Hardware

I decided to use my previous instructable (Programmable LED) as starting point. It consists of a microcontroller, an LED and an Light Dependent Resistor (LDR). That
<http://www.instructables.com/id/Synchronizing-Fireflies/>

should be enough to simulate a simple firefly. It is able to flash, to see and to count.

I just had to modify the program and the orientation of the LED and the LDR. LED and LDR must be placed in a way that one firefly circuit is able to interfere with another. So one LDR must be able to "see" the LED of another firefly. And it should not only see one neighbour but more. That can be done by letting the LED and the LDR pointing up from the ground and use some white paper to reflect the flashes.

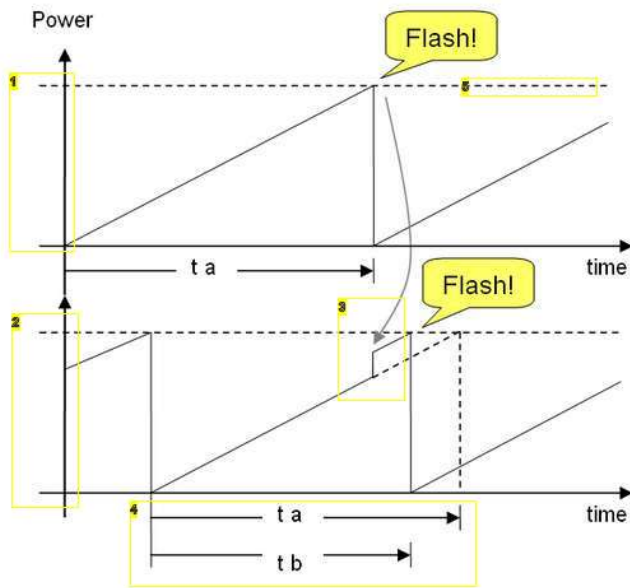


Image Notes

1. Firefly a
2. Firefly b
3. Firefly b sees the flash of firefly a and adds some extra power.
4. Firefly b flashes earlier (t_b) as if it has not seen the flash (t_a). So the two flashes getting closer together.
5. Level of power that is needed to flash.

Step 2: Materials and Tools

For a grid of 5 by 5 fireflies, you need:

- 25 x 1K Ohm resistor
- 25 x 100 Ohm resistor
- 25 x LDR (Light Dependent Resistor), e.g. M9960
- 25 x LED, 1.7V, 20mA (reg, green, blue, what ever you like)
- 25 x ATtiny13, 1KB flash RAM, 64 Bytes RAM, 64 Bytes EEPROM
- 25 x sockets
- prototyping board
- wire

The cost for one firefly should be about 1.50 Euro if you get some rabate when ordering in larger numbers.

The sockets are only neccessary, if your programs are buggy. If you feel confident with your development skills, you can spare them. ;-)

You can surely replace the ATtiny chip with any other microcontroller as PIC, PICAXE or BasicStamp to name a few. Just take the smallest and cheapest you can get. I go with Atmel as I had the programmer already and my first project with a ATtiny13 worked just fine.

Tools

- Soldering iron
- Solder wire
- Breadboard
- AVR programmer
- 5V Power supply or
- 4 AA rechargeables

Software

- WinAVR

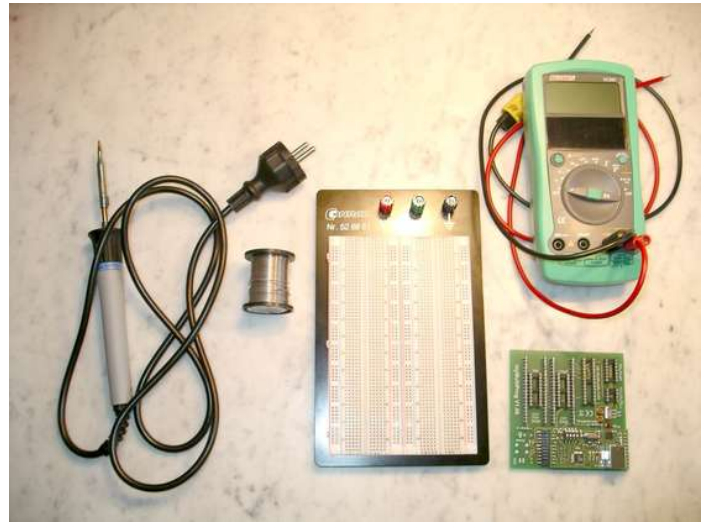
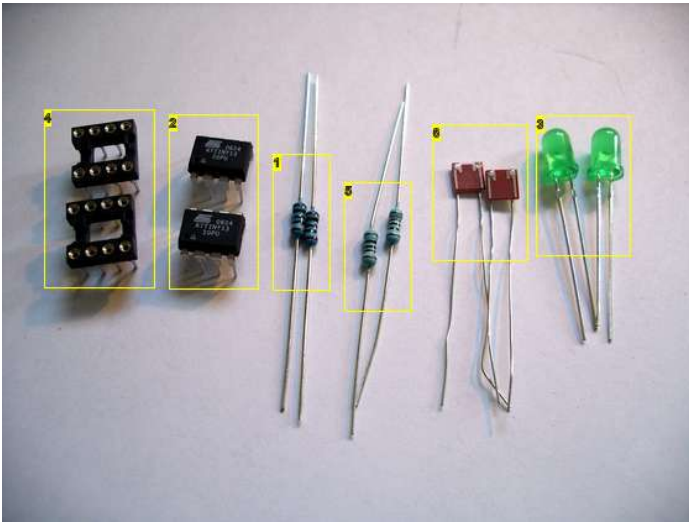
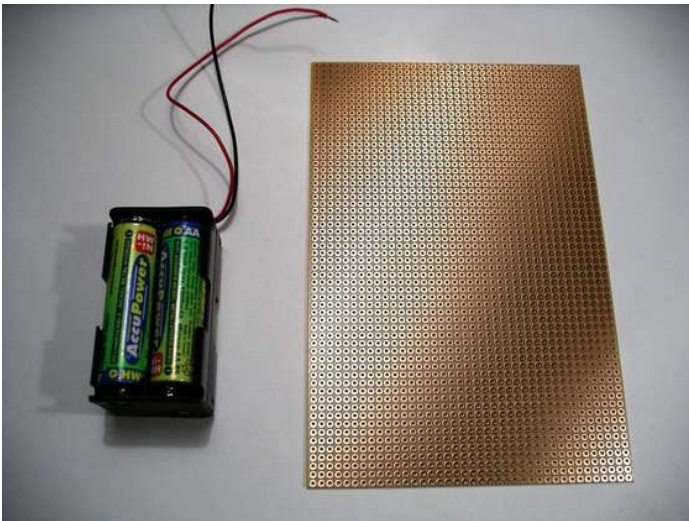


Image Notes

1. 100 Ohm resistors
2. ATtiny13 microcontrollers
3. LEDs, 20mA
4. sockets
5. 1 kOhm resistors
6. LDRs



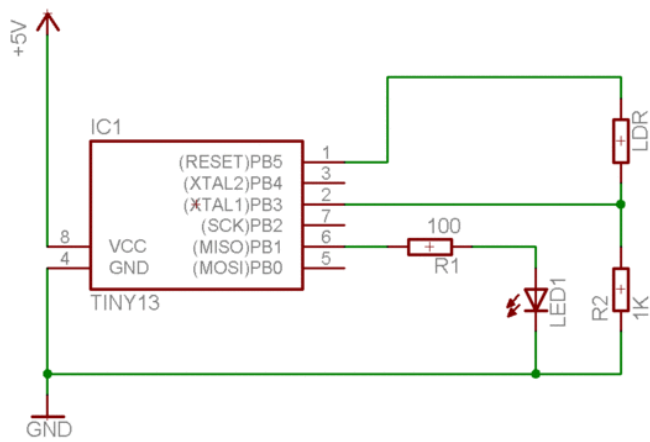
Step 3: The Circuit

The circuit is not very complicated as you see. The LED is connected to an I/O port, the LDR to an ADC port (to enable seeing light differences, not only black and white).

For more details on the circuit see here: [Programmable LED](#) .

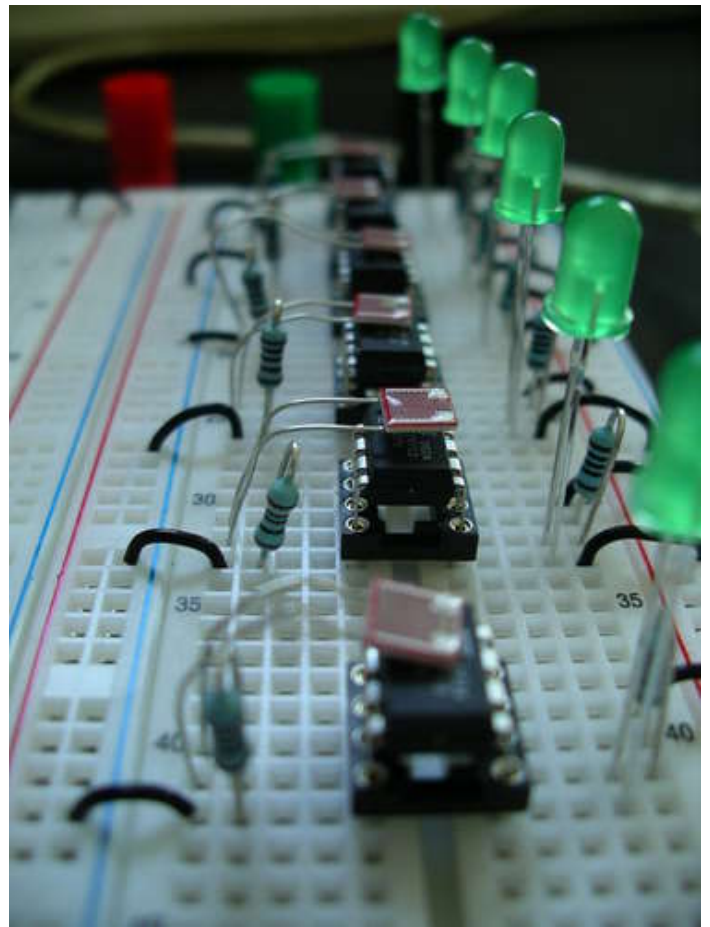
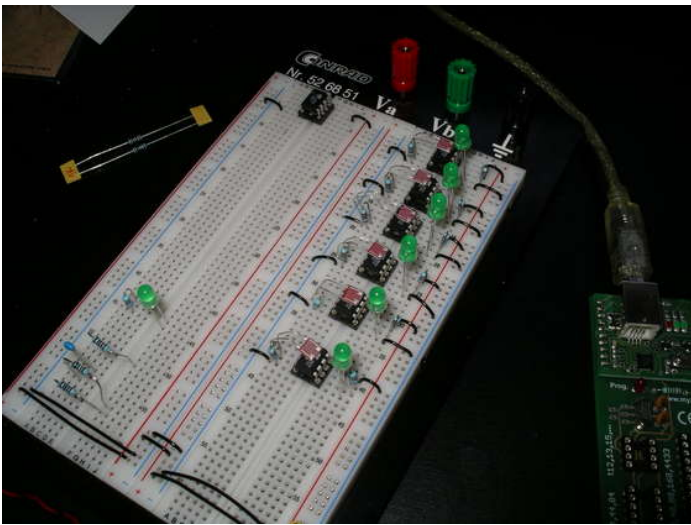
With my last instructable I got some comments about using the LED as light sensor. Yes, using the LED as a sensor. I gave it a try and it basically worked, I could detect light and shadow.

But I was not able to do use it in a more analog way as I was using the LDR before. At least I was not able.



Step 4: On the Breadboard

I started with two up to five fireflies in a row before I moved to the prototype board.



Step 5: On the Prototype Board

As everything works on the breadboard you can move on to use it on a prototype board.

If you are not familiar with soldering, I recommend [this instructable](#).

Reprogramming this thing is not very funny but possible. All controllers are socketed. You have to bend up the LDR a bit and with a bit patience you are able to pull the controller out.

There is a lot of space for improvements. As most of the time.

- Use a printed circuit board (PCB) to save some solder wire and make the soldering and packaging much easier.
- Use SMT components to reduce the size of the circuit.
- Make a board with 10 by 10 fireflies. Or 20 by 20?
- Place the LED near the LDR

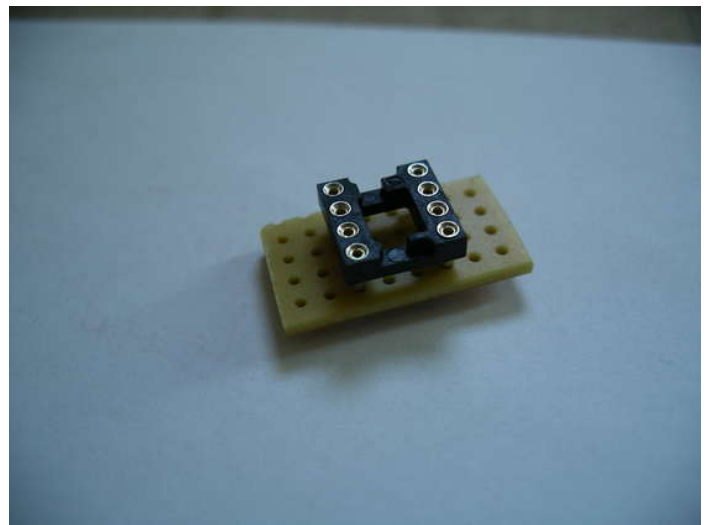
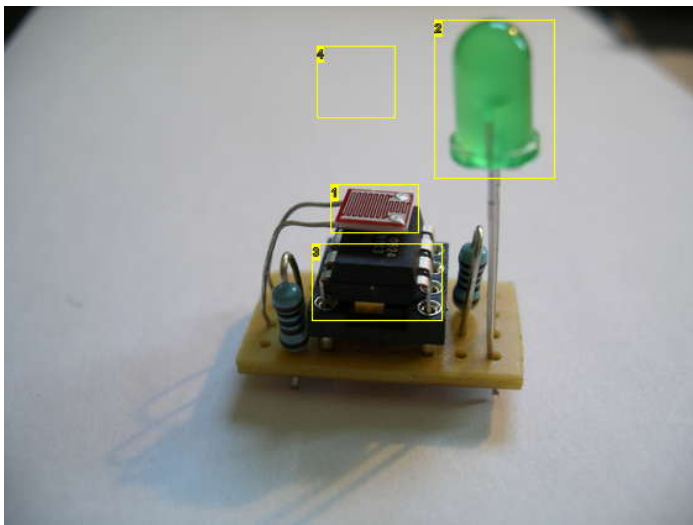
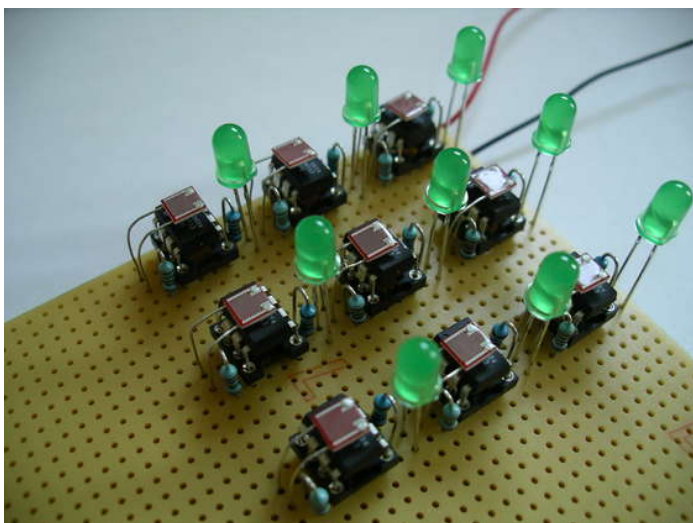
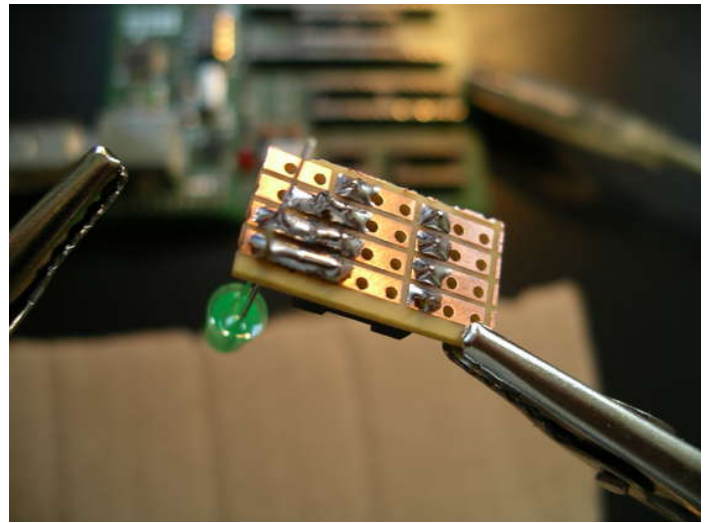
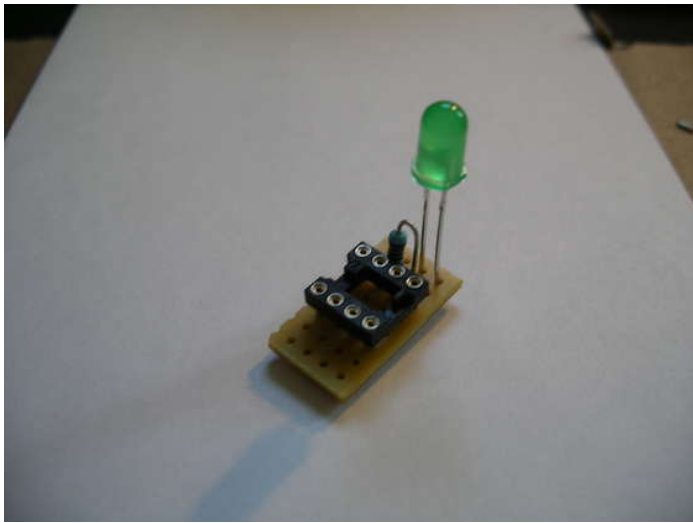


Image Notes

1. Light dependent resistor (LDR)
2. LED, 20mA
3. ATtiny13 microcontroller
4. Make sure you some kind of reflector because the LED will expose most of its light upwards.



Step 6: Software

I will not go into details on how to actually program a microcontroller, there are better pages to learn how to do that. See <http://www.instructables.com/id/E5H5UDWB5UEUKIKV8V/>

The complete program fits into 552 bytes, that makes only 276 instructions on Assembler level. That is pretty nothing, as there is still some startup and configuration code within it. And it consumes only 54.5% of the flash memory so you can still add more features to that.

I bet the core algorithm can be implemented in less than 100 bytes.
Someone?

The steps the program executes are:

```
1. blink 5 times (say hello)2. compute the average brightness and store it3. power = power + 14. if brightness >= daylight (is it daylight?)    * slee
```

Actually this is a bit simplified but you get the idea.

Upload the program and start the fireflies. If everything is ok, they should be able to synchronize in about a minute or two.

I had some problems in getting the fireflies synchronized. As they are running on their internal oscillator, they all have different speeds. I thought it would help to recalibrate them by changing the delay loop of every chip. My girlfriend asked, what I was doing and I told her. She thought, that that is like cheating. Fireflies are not calibrated either. What should I say? She was right. So I decided not to do it and searched for another solution. Keep in mind to go for the easiest solution that could possibly work.

File Downloads



firefly.c (3 KB)

[NOTE: When saving, if you see .tmp as the file ext, rename it to 'firefly.c']



firefly.hex (1 KB)

[NOTE: When saving, if you see .tmp as the file ext, rename it to 'firefly.hex']

Step 7: Conclusion

It is really fun to watch the fireflies, maybe more than building and programming them. You see all sort of patterns that emerge and disappear after some cycles. It can not be predicted and acts chaotic but at some point all fireflies catch up and flash at the same moment. It's like: Yes, they did it. Again.

Hope you enjoyed it.

Kind regards,
Alex

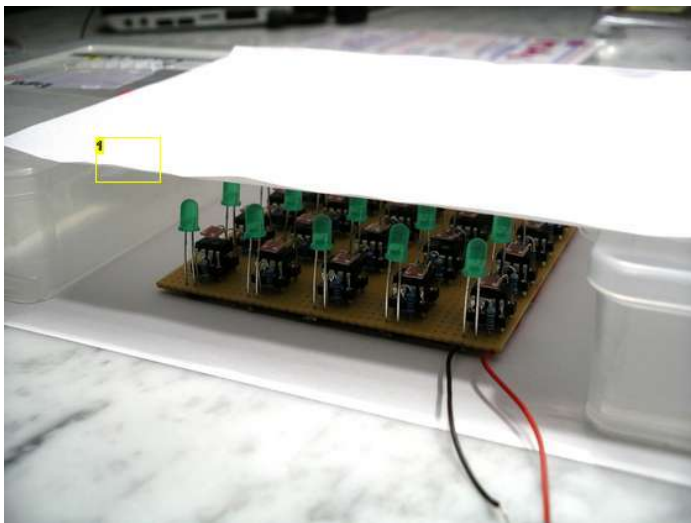


Image Notes

1. This is used as reflector to help the fireflies to see each other.

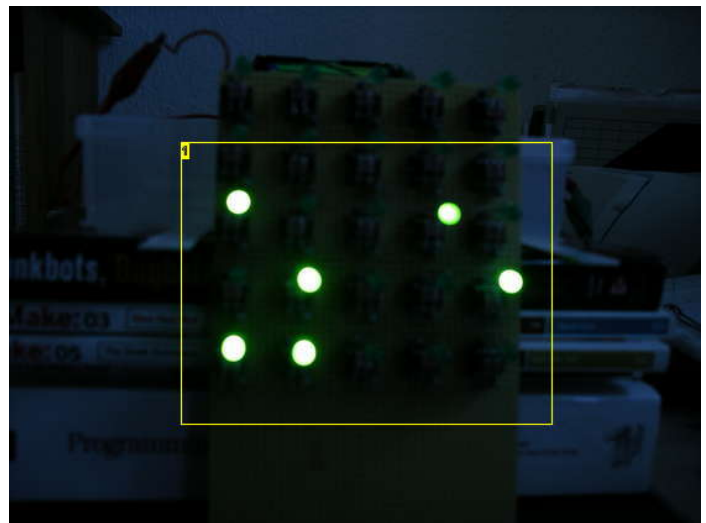


Image Notes

1. Here without the reflector.

Related Instructables



Jar of Fireflies
by kjordahl



Infra-red Remote Intervalometer for Nikon Cameras by jwagnerhki



Jar of Fireflies
by Keso



How to use a 74HC595 Shift Register with a AVR ATtiny13
by roznerd



Blinking, Singing, Marioman by jarv34



Ambient Light Gift Badge by frickelkram

Comments

50 comments

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eulaliaaaa! says:

Aug 5, 2010. 6:28 PM [REPLY](#)

(Piano music) You would not believe your eyes, if ten million fireflies, Ate out your eyes and then farewell. They fill the open air, and scatter body parts everywhere, I don't mean to be rude but an arm is over there.



elektroking says:

May 20, 2010. 2:03 AM [REPLY](#)

Hello
i have a tiny13 and want to put in te program of the fire flies but with mikroc PRO for AVR it doesn't work. Witch programmer have jou used for the program?
Kluzze



AndyGadget says:

May 3, 2010. 4:41 AM [REPLY](#)

Any chance of restoring the video?
I'd really like to see this.



GOWin says:

Dec 27, 2009. 9:35 AM [REPLY](#)

very nice!
Is there a way to "talk" to each firefly (ie ask one to turn itself on or off)?



Ghost Wolf says:

Sep 5, 2009. 7:50 PM [REPLY](#)

Do you need to program every single ic?



alex_weber says:

Sep 6, 2009. 12:40 AM [REPLY](#)

Yes, you have to. Gets a bit tedious, but there is no other way.



Ghost Wolf says:

Sep 6, 2009. 5:10 PM [REPLY](#)

Once you turn it off (0Vs) will the ic lose it's memory?



alex_weber says:

Sep 6, 2009. 11:31 PM [REPLY](#)

Yes and no. Yes, it will loose its main memory. And no, it will not loose its program. The program is stored in flash ram, like on your USB memory stick.



Ghost Wolf says:

Sep 7, 2009. 11:11 AM [REPLY](#)

What is the main memory used for?



alex_weber says:

Sep 7, 2009. 2:39 PM [REPLY](#)

The main memory is used for variables while executing the program. It is used to store, which part of the program is executing right now. If the controller looses power, the main memory is lost. If you turn power on again, it will start the program from the beginning, because it has lost its state. It is like booting up your PC. Data on your harddisk is still there but data in memory is gone. Does that clear things up?



Ghost Wolf says:

Sep 7, 2009. 6:44 PM [REPLY](#)

Yes thank you very much



Ghost Wolf says:
Can you use different LEDs?

Sep 8, 2009. 7:30 PM [REPLY](#)



alex_weber says:
Sure. The sensor detects only brightness, not color.

Sep 8, 2009. 11:28 PM [REPLY](#)



Ghost Wolf says:
Thanks i just wanted to know, a another question I have Is there any photos of the back side?

Sep 9, 2009. 9:17 PM [REPLY](#)



alex_weber says:
No, I'm sorry.

Sep 10, 2009. 1:53 PM [REPLY](#)



Ghost Wolf says:
I was just wondering because I want to how you supply power to the unit

Sep 12, 2009. 11:33 AM [REPLY](#)



Xenel says:
Synchronizing Christmas tree lights anyone?

Mar 7, 2009. 3:43 PM [REPLY](#)



lasermaster3531 says:
cool!!

Jul 18, 2009. 1:13 PM [REPLY](#)



twist2b says:
What if I want to have a couple all over my room, they go off all day, but by night they can synchronize when there is no light. Here is the question though, how large of a distance can you get? And how can you make something like this to work with larger distances?

Jul 1, 2009. 7:30 AM [REPLY](#)



o_k_boy says:
hi alex, great project - i'm a newcomer to avr programming and have been reading your blog and instructables carefully. they have been very useful, so thank you very much. i know this version of firefiles has been superseded now, but in the schematic you have the ldr positioned between pins 1 and 2 of the avr - is this correct or should it be between 2 and 3?

Jun 3, 2009. 1:26 PM [REPLY](#)



alex_weber says:
Hi o_k_boy, yes, you are right, good catch. The ldr is between 2 AND 3. You can check also the source code for the pin definitions. Cheers, Alex

Jun 3, 2009. 2:54 PM [REPLY](#)



uberlum05 says:
Could you do this with 1 arduino board and 5 photoresistor / led combinations??

Jan 25, 2009. 12:29 PM [REPLY](#)



alex_weber says:
Hi uberlum05, yes, you could. But you would loose some of the non deterministic behaviour that arise from using independent devices with slightly different timings. Every firefly has its own internal oscillator and they are all a bit different. If you do it with a single Arduino, I think it will be much less chaotic. Cheers, Alex

Jan 25, 2009. 2:22 PM [REPLY](#)



Carlos Marmo says:
Wonderful work! Much Style! Congratulations!

Oct 30, 2008. 2:56 PM [REPLY](#)



Goodhart says:
Oh cool, a hardware version of Emergence theory.....I will have to have a go at this in the future. :-)

Sep 20, 2008. 4:55 PM [REPLY](#)



kiowamike says:
Great project! I am putting together the parts for this thing but, I am having trouble finding the LDR's. Since I don't speak Dutch or German, I was wondering if you have a Digikey.com part number. Thanks.

Sep 15, 2008. 5:41 PM [REPLY](#)



alex_weber says:

Hi kiowamike,
try this at digikey: <http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail?name=PDV-P9001-ND>
Maybe you have to adjust the resistor connected to the LDR.
Cheers,
Alex

Sep 16, 2008. 8:37 PM [REPLY](#)



kiowamike says:

Thanks a bunch. I'll give it a try and let you know how it works.

Sep 16, 2008. 9:17 PM [REPLY](#)



azog says:

Great project, thinking about doing this. By the way, the link titled "Firefly Synchronization Ad Hoc Networks" (http://www.docomoeurolabs.de/pdf/publications/2006/2006_WSL_Firefly_Synchronization_Ad_Hoc_Networks.pdf) is dead.

Aug 11, 2008. 5:10 AM [REPLY](#)



alex_weber says:

Thanks, I fixed the link.

Aug 11, 2008. 10:32 AM [REPLY](#)



kiss my donkey says:

i would love to do this i know how but i don't know how to program anything. even though give the example in your instructable i would still like to learn to program stuff. is there anything you could recommend? :-)

Jul 4, 2008. 12:08 PM [REPLY](#)



alex_weber says:

If you are absolutely new to controllers and programming I would suggest, that you take a look at two books, "Physical Computing" and "Making Things Talk". These two cover most basic stuff on electronics and microcontroller programming.
Another thing, that might be a good starting point is the Arduino platform. It comes with assembled hardware and an IDE (Integrated Development Environment).
<http://www.arduino.cc>
And Adafruit has nice starter packs. http://www.adafruit.com/index.php?main_page=index&cPath=17
If you are feeling familiar with that, you will understand how to program this thing and how it works.
Cheers,
Alex

Jul 5, 2008. 3:23 AM [REPLY](#)



kiss my donkey says:

I am not really new at them but I'll head down to borders and get those books. but one more thing how did you power them, did you connect them to a battery. if you did that what would the voltage be. or did you just give each one there own battery? Thanx

Jul 7, 2008. 11:26 AM [REPLY](#)



alex_weber says:

No, there are power rails and every firefly is connected to them. I used 4 rechargeable AA batteries (~4.8V) to power them all.

Jul 7, 2008. 12:19 PM [REPLY](#)



kiss my donkey says:

oh, thats neat. once i get those books and some parts i guess i will try this. P.S. this instructable is on of my favorites thanx

Jul 7, 2008. 2:38 PM [REPLY](#)



Oorspronklikheid says:

what would happen if a random selection of the fireflies were programmed to blink at a different rate? BTW very nice instructable

Jun 18, 2008. 9:05 AM [REPLY](#)



alex_weber says:

If the frequency is too different, they won't synchronize any more. At least not as they are programmed at the moment. Maybe if the difference is 1/2f, 2f or 3f, etc.

Jun 18, 2008. 9:43 AM [REPLY](#)



Oorspronklikheid says:

i want it to make a ever changing random pattern

Jun 19, 2008. 10:23 AM [REPLY](#)



Oxide says:

You might like this book:

Self-Organizing Biological Systems - Princeton Studies in Complexity

<http://www.powells.com/biblio?isbn=9780691116242>

ITs also available at B&N. There are a lot of studies on insects as well as other organisms.

Jun 11, 2008. 10:24 AM [REPLY](#)



alex_weber says:
Thanks for the tip. It's now on my wish list ;) Cheers, Alex

Jun 11, 2008. 11:20 AM [REPLY](#)



yedeadd1 says:
hey alex whats the minimum voltage rating of the ATtiny13 chip?

Jun 11, 2008. 10:48 AM [REPLY](#)



alex_weber says:
Hi yedeadd1,
have a look at the datasheet, http://www.atmel.com/dyn/products/Product_card.asp?part_id=3175
It can be run from 1.8V to 5.5V.
Cheers,
Alex

Jun 11, 2008. 11:13 AM [REPLY](#)



yoghurtsniffer says:
if you used diffused LEDs then the light would spread all around it may help also they are cheaper.....i think.. PS my cat would love this she would go insane....lol cool ible

Jun 10, 2008. 12:33 AM [REPLY](#)



alex_weber says:
Actually the LEDs are diffused. At least they are not crystal clear. The problem is the light is emitted with a particular angle, most of the time 20° to 60°. At the moment I am playing with ping pong balls, which looks very promising.

Jun 10, 2008. 11:01 AM [REPLY](#)



winkman says:
oh ok cool thanks

Jun 11, 2008. 3:32 AM [REPLY](#)



bumsugger says:
Excellent Instructable,artificial intelligence (sort of)in its simplest form.

Jun 10, 2008. 7:57 AM [REPLY](#)



=SMART= says:
WOOOoosshhh..... that was the sound of this instructable flying right over my head lol :D, no idea what's going on with the circuitry, but it looks cool neat idea :D

Jun 9, 2008. 2:58 PM [REPLY](#)



FullyInvolvedScientist says:
This is a great idea! How far apart can they be to communicate with each other? Could you enclose these in some sort of capsule or something to help protect them or maybe in the were placed on the ground or in bushes.

May 26, 2008. 10:10 PM [REPLY](#)



alex_weber says:
On the prototype board above they are about 2cm away from each other. It depends on how bright the LEDs are and on how sensitive the light sensor is. A sort of capsule would be great but I am really bad on enclosures.

May 26, 2008. 11:21 PM [REPLY](#)



arphoto says:
I would be really interested in replicating this project, the only problem i have is that i haven't the slightest clue how to program the ATtiny13. Any suggestions?

May 6, 2008. 7:21 AM [REPLY](#)

[view all 105 comments](#)