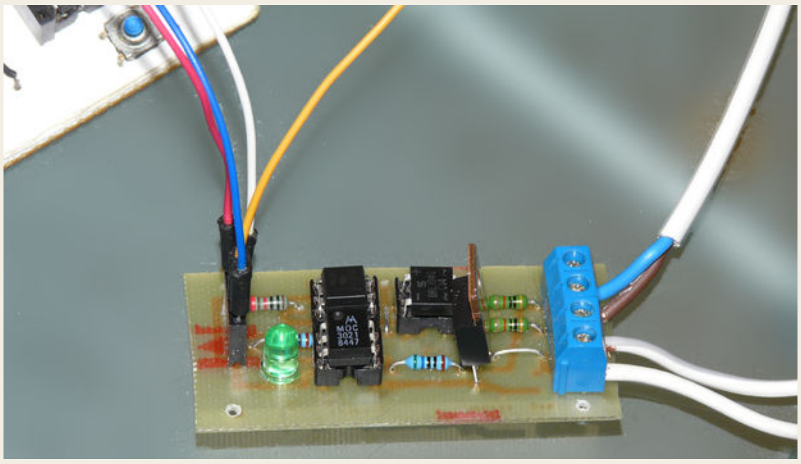
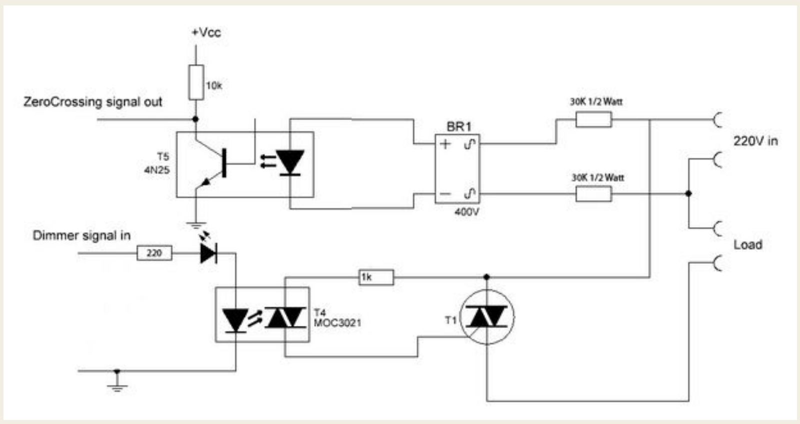
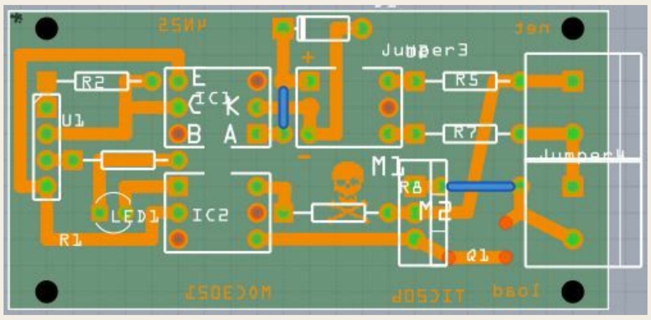
Arduino controlled light dimmer







WARNING: ***Some people try to build this with an optocoupler with zerocrossing coz 'that is better' right? Some are even told in electronics shops it is better to use such an optocoupler. WRONG. This will only work with a random fire optocoupler: NOT igniting at zerocrossing is the principle of this dimmer.***

Switching an AC load with an Arduino is rather simpel: either a mechanical relay or a solid state relay with an optically isolated Triac. (I say Arduino, but if you use an 8051 or PIC16F877A microcontroller, there is stuff for you too here.)

It becomes a bit more tricky if one wants to dim a mains AC lamp with an arduino: just limiting the current through e.g. a transistor is not really possible due to the large power the transistor then will need to dissipate, resulting in much heat and it is also not efficient from an energy use point of view.

Phase cutting
One way of doing it is through phase control with a Triac: the Triac then is fully opened, but only during a part of the sinus AC wave. This is called leading edge cutting.
One could let an Arduino just open the Triac for a number of microseconds, but that has the problem that it is unpredictable during what part of the sinus wave the triac opens and therefore the dimming level is unpredictable. One needs a reference point in the sinus wave.
For that a zero crossing detector is necessary. This is a circuit that tells the Arduino (or another micro controller) when the sinus-wave goes through zero and therefore gives a defined point on that sinus wave.
Opening the Triac after a number of microseconds delay starting from the zero crossing therefore gives a predictable level of dimming.

Pulse Skip Modulation
Another way of doing this is by Pulse Skip Modulation. With PSM, one or more full cycles (sinuswaves) are transferred to the load and then one or more cycles are not. Though effective, it is not a good way to dim lights as there is a chance for flickering. Though it might be tempting, in PSM one should always allow a full sinuswave to be passed to the load, not a half sinus as in that case the load will be fed factually from DC which is not a good thing for most AC loads. The difference between leading edge cutting and PSM is mainly in the software: in both cases one will need a circuit that detects the zero crossing and that can control a triac.

A circuit that can do this is easy to build: The zero crossing is directly derived from the rectified mains AC lines – via an optocoupler of course- and gives a signal every time the wave goes through zero. Because the sine wave first goes through double phased rectification, the zero-crossing signal is given regardless whether the sinus wave goes up through zero or down through zero. This signal then can be used to trigger an interrupt in the Arduino.

It goes without saying that there needs to be a galvanic separation between the Arduino side of things and anything connected to the mains. For those who do not understand 'galvanic separation' it means 'no metal connections' thus ---> opto-couplers. BUT, if you do not understand 'galvanic separation', maybe you should not build this.

The circuit pictured here does just that. The mains 220Volt voltage is led through two 30k resistors to a bridge rectifier that gives a double phased rectified signal to a 4N25 opto-coupler. The LED in this opto-coupler thus goes low with a frequency of 100Hz and the signal on the collector is going high with a frequency of 100Hz, in line with the sinusoid wave on the mains net. The signal of the 4N25 is fed to an interrupt pin in the Arduino (or other microprocessor). The interrupt routine feeds a signal of a specific length to one of the I/O pins. The I/O pin signal goes back to our circuit and opens the LED and a MOC3021, that triggers the Opto-Thyristor briefly. The LED in series with the MOC3021 indicates if there is any current going through the MOC3021. Mind you though that in dimming operation that light will not be very visible because it is very short lasting. Should you chose to use the triac switch for continuous use, the LED will light up clearly.

Mind you that only regular incandescent lamps are truly suitable for dimming. It will work with a halogen lamp as well, but it will shorten the life span of the halogen lamp. It will not work with any cfl lamps, unless they are specifically stated to be suited for a dimmer. The same goes for LED lamps

If you are interested in an AC dimmer such as this but you do not want to try building it yourself, there is a somewhat similar dimmer available at www.inmojo.com, however, that is a 110 Volt 60Hz version (but adaptable for 220 50Hz), that has been out of stock for a while. You will also find a schedule here.

NOTE! It is possible that depending on the LED that is used, the steering signal just does not cut it and you may end up with a lamp that just flickers rather than being smoothly regulated. Replacing the LED with a wire bridge will cure that. The LED is not really necessary. increase the 220 ohm resistor to 470 then

STOP: This circuit is attached to a 110-220 Voltage. Do not build this if you are not confident about what you are doing. Unplug it before coming even close to the PCB. The cooling plate of the Triac is attached to the mains. Do not touch it while in operation. Put it in a proper enclosure/container.

WAIT: Let me just add a stronger warning here: This circuit is safe if it is built and implemented only by people who know what they are doing. If you have no clue or if you are doubting about what you do, chances are you are going to be DEAD! DO NOT TOUCH WHEN IT IS CONNECTED TO THE GRID

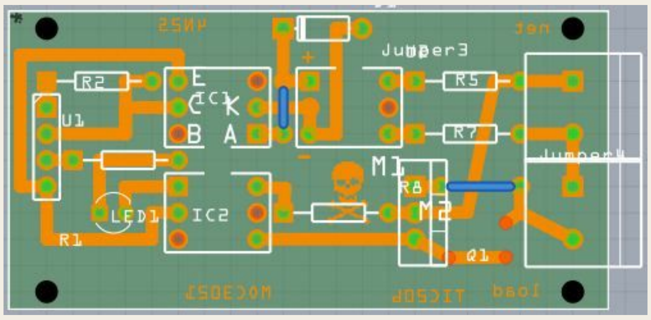
Materials
Zerocrossing
4N25 €0.25 or H11AA1 or IL250, IL251, IL252, LTV814 (see text in the next step)
Resistor 10k €0.10
bridge rectifier 400 Volt €0.30
2x 30 k resistor 1/2 Watt (resistors will probably dissipate 400mW max each €0.30
1 connector €0.20
5.1 Volt zenerdiode (optional)

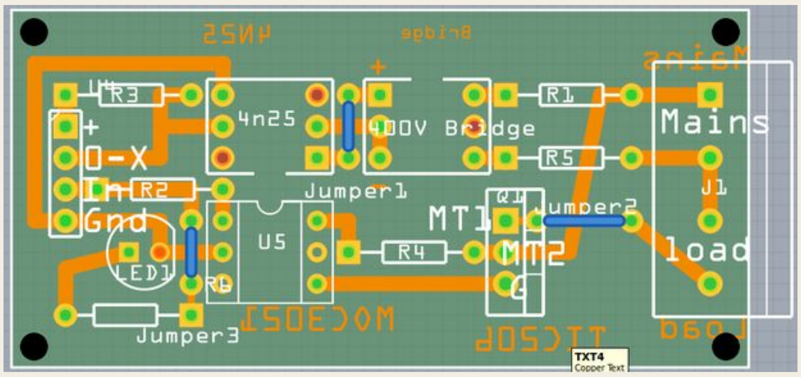
Lamp driver
LED (Note: you can replace the LED with a wire bridge as the LED may sometimes cause the lamp to flicker rather than to regulate smoothly)
MOC3021 If you chose another type, **make sure it has NO zero-crossing detection**, I can't stress this enough DO NOT use e.g. a MOC3042
Resistor 220 Ohm €0.10 (I actually used a 330 Ohm and that worked fine)
Resistor 470 Ohm-1k (I ended up using a 560 Ohm and that worked well)
TRIAC TIC206 €1.20 or BR136 €0.50
1 connector €0.20

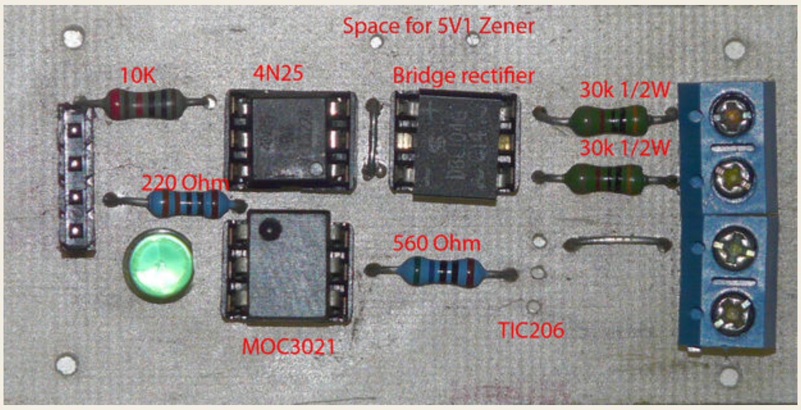
Other
Piece of PCB 6x3cm
electric wiring

That is about €3 in parts

Step 1: Arduino controlled light dimmer: The PCB







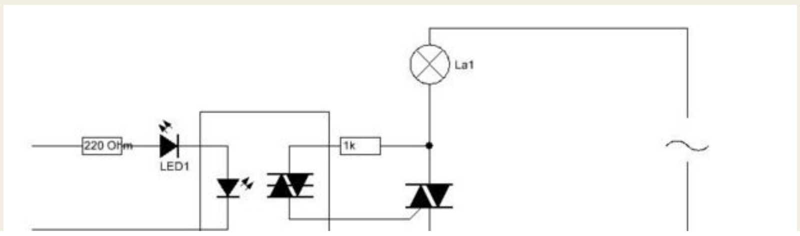
You will find two pictures for the PCB: my first one, that I leave here for documentation purposes and a slightly altered new one. The difference is that I left out the zenerdiode as it is not really necessary and I gave the LED itś own (1k) resistor: it is no longer in series with the Optocoupler, that now has a 470 Ohm resistor. I made the PCB via direct toner transfer and then etched it in a hydrochloric acid/Hydrogenperoxide bath. There are plenty of instructables telling how to do that. You can use the attached print design to do the same. Populating the print is quite straightforward. I used IC feet for the opto-couplers and the bridge rectifier.
Download the print here.
Note: You need Fritzing for this. For the direct toner transfer, the printed side of the printed pdf file, goes directly against the copper layer for transfer. Once it is transferred, you will be looking at the ink from the other side and thus see the text normal again. I made slight alterations in thePCB: I removed the zenerdiode and the LED is no longer in series with the optocoupler.

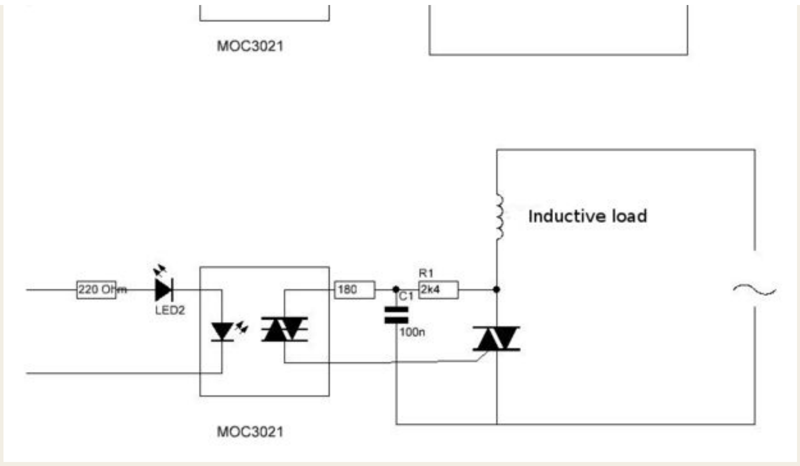
I used a TIC206. That can deliver 4 amperes. Keep in mind though that the copper tracks of the PCB will not be able to withstand 4 Amperes. For any serious load, solder a piece of copper installation wire on the tracks leading from the TRIAC to the connectors and on the track between the two connectors.

In case it is not clear what the inputs are: from top to bottom on the second picture:
+5Volts
Interrupt signal (going to D2 on arduino)
Triac signal (coming from D3 on Arduino)
Ground

NOTE:
If you have an H11AA1or IL 250, 251 or 252 opto-coupler then you do not need the bridge rectifier. These have two anti-parellel diodes and thus can handle AC. It is pin compatible with the 4N25, just pop it in and solder 2 wire-bridges between R5 and + and R7 and -. The LTV814 is not pincompatible

Step 2: A word on inductive loads: theory



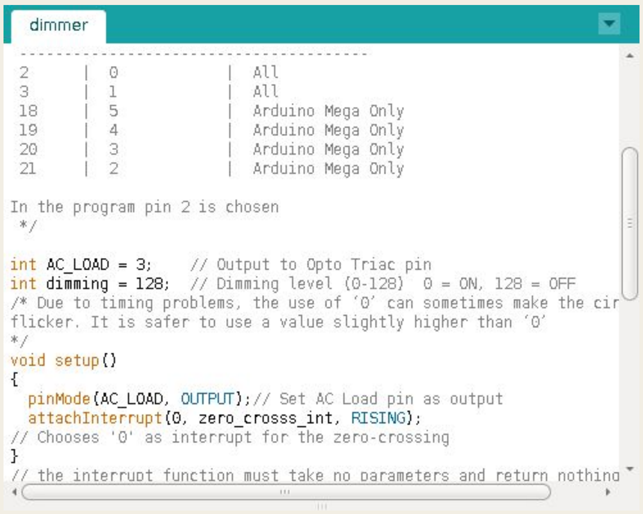


The presented circuit is suited for pure resistive loads such as incandescent lamps.
Should you want to use it for inductive loads, then a snubber circuit is necessary. The figure shows the modifications for use with Inductive loads. Mind you, this is not something I tried as I just wanted to dim lamps, but it is based on examples and theory available on the internet. You would have to adapt the provided PCB
The top figure shows the circuit as is, for dimming a lamp. It is in all its simplicity just a resistor to trigger the gate via the diac in the optocoupler. The value of 1k may be changed as discussed in the text before.
The bottom figure gives an omnipresent circuit for use in inductive loads.

It consists of an additional resistor and capacitor. The gate current is below 15mA. If you are using a less sensitive triac to control the inductive load, reduce the resistor from 2.4kΩ to 1.2kΩ, providing more current to drive the triac and increase the capacitor to 200nF. This snubber circuit is there to protect the triac from the high voltage generated from an inductive load. The feedback may cause some problem for non-inductive load. The small leakage can be significant enough to turn on small load (for example a lamp).

There are other snubber circuits, e.g. a resistor and capacitor in series directly over the load

Step 3: The software, a bit of theory



```
 ---------------------------------------
 2      |  0             |  All
 3      |  1             |  All
 18     |  5             |  Arduino Mega Only
 19     |  4             |  Arduino Mega Only
 20     |  3             |  Arduino Mega Only
 21     |  2             |  Arduino Mega Only

In the program pin 2 is chosen
 */

int AC_LOAD = 3;    // Output to Opto Triac pin
int dimming = 128;  // Dimming level (0-128)  0 = ON, 128 = OFF
/* Due to timing problems, the use of ‘0’ can sometimes make the cir
flicker. It is safer to use a value slightly higher than ‘0’
*/
void setup()
{
  pinMode(AC_LOAD, OUTPUT);// Set AC Load pin as output
  attachInterrupt(0, zero_crosss_int, RISING);
// Chooses '0' as interrupt for the zero-crossing
}
// the interrupt function must take no parameters and return nothing
```

If you could care less about the theory, but just want the software, go to the next step

The way to use an AC dimmer/fader is quite simple once you understand the basics:

In AC the power fed to the lamp is directly related to the total surface of the sinuswave, the lamp can be regulated by only allowing a predictable part of that sinuswave to flow through the lamp.

As such we need a reference point on that sinus from where we calculate when the lamp has to be switched on.

The easiest reference point to use is the so called 'zero crossing': the moment that the light goes through zero.
After each zero crossing there is one full half of the sinuswave available to send through the lamp.

So what the software needs to do is to detect the zerocrossing, and then wait for a set amount of time on that sinuswave to switch on the TRIAC.

There are 2 major net frequencies in the world: 100Hz in Europe and most of Asia and Africa and 120 Hz in the America's (and parts of the Caribean).
There are 2 major voltages in the world: 110-120V and 220-240V but they are not important for the mathematics here.

For ease of use I will take the 50Hz frequency as an example:
50Hz is 50 waves per second.
Each sinuswave thus takes 1000ms/50=20ms (miliseconds)
As there are 2 sinuspeaks in a wave that means that after every zero detection there is a 10ms period that we can regulate.
Should we ignite the lamp directly at the beginning of that period, the lamp will receive full power, should we do it at the end of that 10ms period the lamp will receive no ower and should we do it halfway, the lamp will receive half power.

As we are using TRIACs, what the software needs to do is to wait for the zero point at the sinuscurve, take note of that and then wait a specified amount of time within that 10ms period to send a pulse to the TRIAC.
If it sends that pulse at 5ms, the lamp will only burn at half power.

In the Circuit, the zero detection is done by the biphase optocoupler and is available as the X-signal on the board.
There are basically 2 ways for a microcontroller to detect that signal:
1-a continuous 'polling' of the Zero Crossing pin
2-using an interrupt to tell the program that there was a zero crossing
The main difference between the two is that in 'polling' everytime the computer goes through it's main loop it needs to check the pin. If your program is busy doing a lot of other things, it might be too late in checking the zero crossing pin, while when using an interrupt, it does not matter what the program is busy with. The interrupt is sort of 'tapping it on the shoulder' saying "Hey look, something came up that you need to attend to NOW".

After the zero crossing is detected the program needs to wait for a specified amount of time and then switch on the TRIAC.
Also here, that waiting can be done in two different ways
1- by issuing a 'wait' command
2-by using a timer interrupt

Again, both these methods have their pro's and con's. The 'wait' command ('delay' in Arduino language) literally let's the computer wait for the required time and it cant do anything else in the mean time. if the lamp is burning at low power by letting the computer wait say 9ms, that means that every 10ms the computer is told to wait 9ms: ergo it will be idle 90% of the time. That is fine if your controller is only used to control the lamp, but if it needs to do other stuff then little time is left.
Using a timer interrupt solves that. Basically what that does is that the program tells the timer: ¨Hey, I just heard we have a zero crossing, I got to do something else, but you just wait 4.5ms and then switch on the Triac" So the program goes on it's merry way and 4.5ms (as an example) after it was given notice there was a 0-crossing, the timer switches on the TRIAC.

Polling: (note this is a rough example for illustration of polling, obviously it needs some enhancement)

```
int AC_LOAD=3; //   We use pin 3 to ignite the TRIAC
int state; // integer to store the status of the zero crossing

void setup()
{
pinMode(AC_LOAD, OUTPUT);// Set AC Load pin as output
}

void loop()
{
state=digitalRead(AC_LOAD);
if (state=1) {
delayMicroseconds(5000); // =5 ms=half power
digitalWrite(AC_LOAD, HIGH);   // triac firing
}
```

Interrupt driven:
To use an interrupt, first we need to set that up. On the Arduino that is as follows:

```
void setup()
{
  pinMode(AC_LOAD, OUTPUT);// Set AC Load pin as output
  attachInterrupt(0, zero_crosss_int, RISING);  // Choose the zero cross interrupt # from the table
}
```

What this says is that the interrupt is attached to interrupt 0, it goes to a function called "zero_crosss_int" and it reacts to a rising flank on the pin.

In the Zero_cross_int function that the program jumps to after the interrupt we determine the time we need to wait before firing the TRIAC. We will also add a bit of functionality. We don't just want one level set that the lamp burns on, we are going to add some functionality to regulate the light level in steps.
For that I have chosen the fully arbitrary amount of 128 steps. That means that every step is 10ms/128 = 10000us/128=75us (in fact it is 78, but I get to that later). The total dimtime then is calculated from 75x(1 to 128). The number between 1-128, which determines our level of dimming, we assign to the variable integer 'dimming'

```
void zero_crosss_int()  // function to be fired at the zero crossing to dim the light
{
  int dimtime = (75*dimming);    // For 60Hz =>65
  delayMicroseconds(dimtime);    // Off cycle
  digitalWrite(AC_LOAD, HIGH);   // triac firing
  delayMicroseconds(10);         // triac On propagation delay (for 60Hz use 8.33)
  digitalWrite(AC_LOAD, LOW);    // triac Off
}
```

What happens here is that the program first calculates the dimtime (=time to wait before the triac is fired)
It then waits that amount of time, subsequently waits that amount of time and fires the Triac. The Triac will switch off again at the following zero crossing, but we are going to already write a low on the TRIAC pin to avoid accidental ignition in the next cycle. We need to wait a bit however to know for sure the TRIAC is on, so we wait 10us. Now (10000-10)/128 is still 87 but i found 75 to work well. Feel free to use 78 though.
The only thing then left to do in the main program is to set the level at which we want the lamp to burn:

```
void loop()  {
  for (int i=5; i <= 128; i++){
    dimming=i;
    delay(10);
   }
```

What happens here is a simple loop that regulates the lamp up in a 128 steps. I have chosen not to start at 1 but at 5 because at that level there could be some timing issues that could cause the lamp to flicker.

The above program is only an example of how to control the lamp, obviously you want to add some other functionality rather than just have a lamp go up and down in brightness.

Using a timer:
If you want your program to be time efficient you will need to use an interrupt for the zero-crossing detection and a timer to determine the amount of time to wait.
Roughly a program would look as follows:

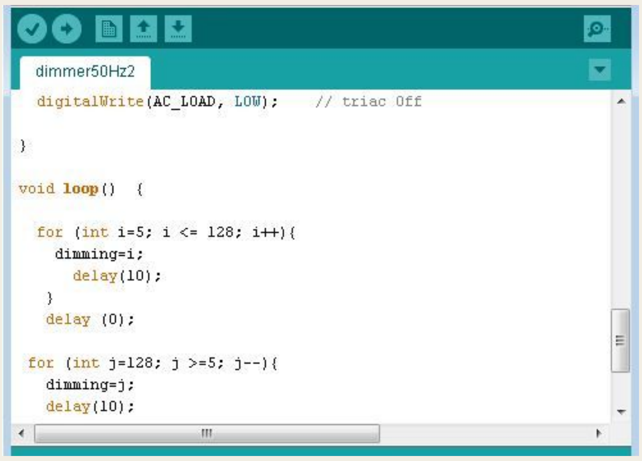
Initialize
Set up the various constants and variables you need and include the libraries used (such as the TimerOne Library)

Setup
Setp the pins and the 2 interrupts
The zero-crosssing interrupt points to a function and so does the timer interrupt

Zero-*cross functie*
Set a boolean indicating if a zero cross has occurred

Timer function
If we regulate the brightness again in 128 steps, then the timer function is set up to be called whenever the time of a step has passed (e.g. 75us) and then checks if the number of steps passed is equal to the number of steps set. If that is the case, the Triac is switched on

Step 4: Arduino controlled light dimmer: The software



```
  digitalWrite(AC_LOAD, LOW);    // triac Off

}

void loop()  {

  for (int i=5; i <= 128; i++){
    dimming=i;
      delay(10);
   }
   delay (0);

 for (int j=128; j >=5; j--){
   dimming=j;
   delay(10);
```

As discussed in the previous theoretical page, the software is fairly easy.
If you want to develop your own software all you need to do is:
Wait for the zerocrossing
Wait a specific time between 0 and 9090 microseconds (9090=10.000-10)
switch on yr TRIAC
Wait for about 10us (that is the time you need to make sure the TRIAC is on)
switch off yr TRIAC (in fact, you only remove the triggersignal to the TRIAC, the TRIAC will stay on till the next zerocrossing)

I just briefly sketch the flow of the program that I used:
(make sure you read the 'NOTE' below)
The zero X-ing signal generates an interrupt.
At 50Hz that interrupt is every 10ms or 10.000uS
At 60Hz that interrupt is every 8.333 ms or 8333 uS
The interrupt routine then switches on the Triac after a specific time. That time is set in the main program loop.
As the program varies the dimming from Full to Off in 128 steps (that is just a choice that was made, could be 100 steps as well), at 50 Hz we need the steps to be 75 uS and at 60Hz they need to be 65 uS

It works as follows:
The interrupt function"zero_crosss_int" gets called every time a zero-crossing is detected, which is 100times/second. It's only function is to set the time

that the Triac is switched on to the value of the variable 'dimming'
In the main loop of the program the actual value of that variable is set

```
/*

AC Voltage dimmer with Zero cross detection
Author: Charith Fernanado <a href="http://www.inmojo.com"> http://www.inmojo.com
<>
Adapted by DIY_bloke
License: Creative Commons Attribution Share-Alike 3.0 License.
Attach the Zero cross pin of the module to Arduino External Interrupt pin
Select the correct Interrupt # from the below table
(the Pin numbers are digital pins, NOT physical pins:
digital pin 2 [INT0]=physical pin 4 and digital pin 3 [INT1]= physical pin 5)
check: <a href="http:/rduino.cc/en/Referencettachinterrupt"> http://www.inmojo.com
<>

Pin    |  Interrrupt # | Arduino Platform
---------------------------------------
2      |  0            |  All -But it is INT1 on the Leonardo
3      |  1            |  All -But it is INT0 on the Leonardo
18     |  5            |  Arduino Mega Only
19     |  4            |  Arduino Mega Only
20     |  3            |  Arduino Mega Only
21     |  2            |  Arduino Mega Only
0      |  0            |  Leonardo
1      |  3            |  Leonardo
7      |  4            |  Leonardo
The Arduino Due has no standard interrupt pins as an iterrupt can be attached to almosty any pin.

In the program pin 2 is chosen
*/
int AC_LOAD = 3;    // Output to Opto Triac pin
int dimming = 128;  // Dimming level (0-128)  0 = ON, 128 = OFF

void setup()
{
  pinMode(AC_LOAD, OUTPUT);// Set AC Load pin as output
  attachInterrupt(0, zero_crosss_int, RISING);  // Choose the zero cross interrupt # from the table
}

//the interrupt function must take no parameters and return nothing
void zero_crosss_int()  //function to be fired at the zero crossing to dim the light
{
  // Firing angle calculation : 1 full 50Hz wave =1/50=20ms
  // Every zerocrossing thus: (50Hz)-> 10ms (1/2 Cycle)
  // For 60Hz => 8.33ms (10.000/120)
  // 10ms=10000us
  // (10000us - 10us) / 128 = 75 (Approx) For 60Hz =>65

  int dimtime = (75*dimming);    // For 60Hz =>65
  delayMicroseconds(dimtime);    // Wait till firing the TRIAC
  digitalWrite(AC_LOAD, HIGH);   // Fire the TRIAC
  delayMicroseconds(10);         // triac On propogation delay (for 60Hz use 8.33)
  digitalWrite(AC_LOAD, LOW);    // No longer trigger the TRIAC (the next zero crossing will swith i
}

void loop()  {
  for (int i=5; i <= 128; i++){
    dimming=i;
    delay(10);
   }
}
```

About the software: theoretically in the loop you could let variable 'i' start from '0'. However, since the timing in the interrupt is a bit of an approximation using '0' (fully on) could screw up the timing a bit. the same goes for 128 (Full off) though that seems to be less critical. Wether '5' or perhaps '1' is the limit for your set up is a matter of trying, your range may go from e.g. 2 to 126 instead of 0-128. If anybody has a more precise way to set up the timing in the interrupt I'd be happy to hear it.
Ofcourse it is not necessary to work with interrupts. It is also possible to keep polling the zero crossing pin for going to 0.

Though the software works with an interrupt to determine the moment of zero crosssing, it is still not so efficient because the time (dimtime) we need to wait after the zero crossing before the triac is fired is literally spent 'waiting' in the zero cross interrupt function.

It would be more efficient to set a timer interrupt to fire at the right moment so in the mean time the arduino can do something else. Such a program can be found in step

NOTE

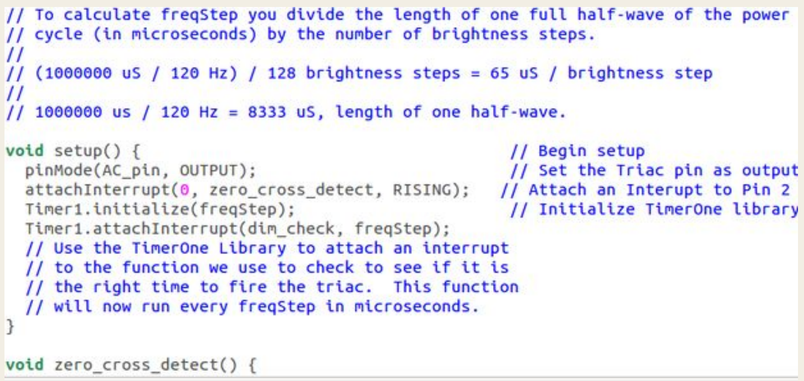
Let me just reiterate the above statement: This program is a demo of how you can control the dimmer. It is NOT and efficient program as it spends most of its time waiting. It is therefore NOT the most suitable to combine with other tasks of the processor. If you need a more efficient program use a timer instead of delay

Step 5: Arduino Controlled Lightdimmer: The Software II

I found another piece of Software that allows controlling the lamp via the serial port. I have not tested it myself yet, but I see no reason why it should not work. It triggers on the falling edge of the zero-crossing signal, so the timing is a bit different.

```
int AC_pin = 3;//Pin to OptoTriac
byte dim = 0; //Initial brightness level from 0 to 255, change as you like!

void setup() {
  Serial.begin(9600);
  pinMode(AC_pin, OUTPUT);
  attachInterrupt(0, light, FALLING);//When arduino Pin 2 is FALLING from HIGH to LOW, run light pro
}

void light() {
  if (Serial.available()) {
    dim = Serial.read();
    if (dim < 1) {
      //Turn TRIAC completely OFF if dim is 0
      digitalWrite(AC_pin, LOW);
    }

    if (dim > 254) { //Turn TRIAC completely ON if dim is 255
      digitalWrite(AC_pin, HIGH);
    }
  }

  if (dim > 0 && dim < 255) {
    //Dimming part, if dim is not 0 and not 255
    delayMicroseconds(34*(255-dim));
    digitalWrite(AC_pin, HIGH);
    delayMicroseconds(500);
    digitalWrite(AC_pin, LOW);
  }
}
void loop() {
}


Even more software <a href="http://wiki.dxarts.washington.edu/groups/general/wiki/4dd69/AC_Dimmer_Ci
```

Step 6: Arduino controlled light dimmer: The software III



```
// To calculate freqStep you divide the length of one full half-wave of the power
// cycle (in microseconds) by the number of brightness steps.
//
// (1000000 uS / 120 Hz) / 128 brightness steps = 65 uS / brightness step
//
// 1000000 us / 120 Hz = 8333 uS, length of one half-wave.

void setup() {                                      // Begin setup
  pinMode(AC_pin, OUTPUT);                          // Set the Triac pin as output
  attachInterrupt(0, zero_cross_detect, RISING);   // Attach an Interupt to Pin 2
  Timer1.initialize(freqStep);                      // Initialize TimerOne library
  Timer1.attachInterrupt(dim_check, freqStep);
  // Use the TimerOne Library to attach an interrupt
  // to the function we use to check to see if it is
  // the right time to fire the triac.  This function
  // will now run every freqStep in microseconds.
}

void zero_cross_detect() {
```

The code below has been confirmed to work on the Leonardo

```
/*
AC Light Control

 Updated by Robert Twomey
 Changed zero-crossing detection to look for RISING edge rather
 than falling.  (originally it was only chopping the negative half
 of the AC wave form).

 Also changed the dim_check() to turn on the Triac, leaving it on
 until the zero_cross_detect() turn's it off.

 Adapted from sketch by Ryan McLaughlin
 <a href="http://www.arduino.cc/cgi-bin/yabb2/YaBB.pl?num=1230333861/30" rel="nofollow"> <a rel="nof
(now here: <a rel="nofollow"> http://www.arduino.cc/cgi-bin/yabb2/YaBB.pl?num=1...<>

 */

#include  <TimerOne.h>          // Avaiable from <a href="http://www.arduino.cc/playground/Code/Time
<>
volatile int i=0;               // Variable to use as a counter
volatile boolean zero_cross=0;  // Boolean to store a "switch" to tell us if we have crossed zero
int AC_pin = 11;                // Output to Opto Triac
int dim = 0;                    // Dimming level (0-128)  0 = on, 128 = 0ff
int inc=1;                      // counting up or down, 1=up, -1=down

int freqStep = 75;    // This is the delay-per-brightness step in microseconds.
                      // For 60 Hz it should be 65
// It is calculated based on the frequency of your voltage supply (50Hz or 60Hz)
// and the number of brightness steps you want.
//
// Realize that there are 2 zerocrossing per cycle. This means
// zero crossing happens at 120Hz for a 60Hz supply or 100Hz for a 50Hz supply.

// To calculate freqStep divide the length of one full half-wave of the power
// cycle (in microseconds) by the number of brightness steps.
//
// (120 Hz=8333uS) / 128 brightness steps = 65 uS / brightness step
// (100Hz=10000uS) / 128 steps = 75uS/step

void setup() {                                      // Begin setup
  pinMode(AC_pin, OUTPUT);                          // Set the Triac pin as output
  attachInterrupt(0, zero_cross_detect, RISING);    // Attach an Interupt to Pin 2 (interupt 0) for
  Timer1.initialize(freqStep);                      // Initialize TimerOne library for the freq we n
  Timer1.attachInterrupt(dim_check, freqStep);
  // Use the TimerOne Library to attach an interrupt
  // to the function we use to check to see if it is
  // the right time to fire the triac.  This function
  // will now run every freqStep in microseconds.
}

void zero_cross_detect() {
  zero_cross = true;               // set the boolean to true to tell our dimming function that a ze
  i=0;
  digitalWrite(AC_pin, LOW);       // turn off TRIAC (and AC)
}

// Turn on the TRIAC at the appropriate time
void dim_check() {
  if(zero_cross == true) {
    if(i>=dim) {
      digitalWrite(AC_pin, HIGH); // turn on light
      i=0;  // reset time step counter
      zero_cross = false; //reset zero cross detection
    }
    else {
      i++; // increment time step counter
    }
  }
}

void loop() {
  dim+=inc;
  if((dim>=128) || (dim<=0))
    inc*=-1;
  delay(18);
}
```

Step 7: Software To set level using up and down buttons

Below a code to set the light level with up and down buttons. It uses a timer that checks for the time necessary to trigger the TRIAC, rather than wait in a delay loop

```
/*
AC Light Control
Uses up and down buttons to set levels
makes use of a timer interrupt to set the level of dimming
*/
#include <TimerOne.h>           // Avaiable from http://www.arduino.cc/playground/Code/Timer1

volatile int i=0;               // Variable to use as a counter of dimming steps. It is volatile sin
volatile boolean zero_cross=0;  // Flag to indicate we have crossed zero
int AC_pin = 3;                 // Output to Opto Triac
int buton1 = 4;                 // first button at pin 4
int buton2 = 5;                 // second button at pin 5
int dim2 = 0;                   // led control
int dim = 128;                  // Dimming level (0-128)  0 = on, 128 = 0ff
int pas = 8;                    // step for count;
int freqStep = 75;              // This is the delay-per-brightness step in microseconds. It allows
                                // If using 60 Hz grid frequency set this to 65


void setup() {  // Begin setup
  Serial.begin(9600);
  pinMode(buton1, INPUT);  // set buton1 pin as input
  pinMode(buton2, INPUT);  // set buton1 pin as input
  pinMode(AC_pin, OUTPUT);                          // Set the Triac pin as output
  attachInterrupt(0, zero_cross_detect, RISING);    // Attach an Interupt to Pin 2 (interupt 0) for
  Timer1.initialize(freqStep);                      // Initialize TimerOne library for the freq we n
  Timer1.attachInterrupt(dim_check, freqStep);      // Go to dim_check procedure every 75 uS (50Hz)
  // Use the TimerOne Library to attach an interrupt

}

void zero_cross_detect() {
  zero_cross = true;               // set flag for dim_check function that a zero cross has occured
  i=0;                             // stepcounter to 0.... as we start a new cycle
  digitalWrite(AC_pin, LOW);
}

// Turn on the TRIAC at the appropriate time
// We arrive here every 75 (65) uS
// First check if a flag has been set
// Then check if the counter 'i' has reached the dimming level
// if so.... switch on the TRIAC and reset the counter
void dim_check() {
  if(zero_cross == true) {
    if(i>=dim) {
      digitalWrite(AC_pin, HIGH);  // turn on light
      i=0;  // reset time step counter
      zero_cross=false;    // reset zero cross detection flag
    }
    else {
      i++;  // increment time step counter
    }
  }
}

void loop() {
  digitalWrite(buton1, HIGH);
  digitalWrite(buton2, HIGH);

 if (digitalRead(buton1) == LOW)
   {
  if (dim<127)
  {
    dim = dim + pas;
    if (dim>127)
    {
      dim=128;
    }
  }
```

```
   }
  if (digitalRead(buton2) == LOW)
   {
  if (dim>5)
  {
     dim = dim - pas;
  if (dim<0)
    {
      dim=0;
    }
   }
   }
    while (digitalRead(buton1) == LOW) {  }
    delay(10); // waiting little bit...
    while (digitalRead(buton2) == LOW) {  }
    delay(10); // waiting little bit...


  dim2 = 255-2*dim;
  if (dim2<0)
  {
    dim2 = 0;
  }

  Serial.print("dim=");
  Serial.print(dim);
  Serial.print("     dim2=");
  Serial.print(dim2);
  Serial.print("     dim1=");
  Serial.print(2*dim);
  Serial.print('\n');
  delay (100);

}
```

Step 8: Arduino controlled lightdimmer: result & expansion

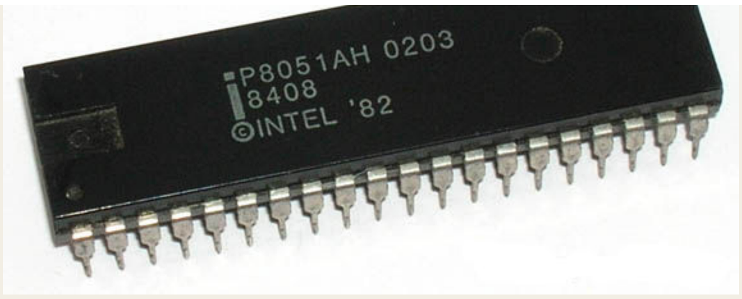
Just a quick cellphone recorded video of it's workings

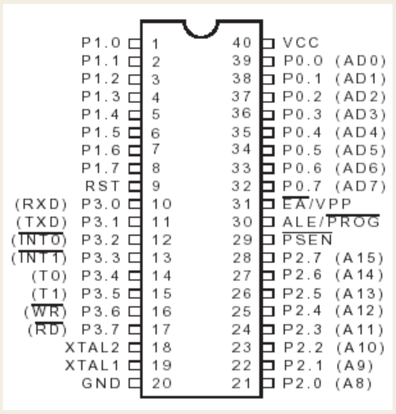
3 channels
This circuit can also be used for an RGB mixer, albeit you need two additional TRIAC circuits. You could use this circuit+PCB in duplo for that, but make sure you use a random cycle opto-coupler suah as the MOC3021. Do not use a zerocrossing Opto-coupler such as the MOC3041.
I now made a 3 channel Ibble

The zero-crossing circuit is ofcourse only needed once.
Perhaps this is still something for tradition (call it Old fashioned): x-mas tree lights that work directly on 220 (or 110) Volts. Hang 3 different color lamp strings in the tree and regulate them with this circuit expanded with two TRIAC circuits

Frequency
Depending on the grid frequency (either 50 or 60) different step values need to be set manually. However, it is possible to let the software determine the frequency in a setup routine, e.g. by meauring the time between two zero crossings or count the number of zerocriossings within a set time.

Step 9: 8051 Controlled lightdimmer: Software



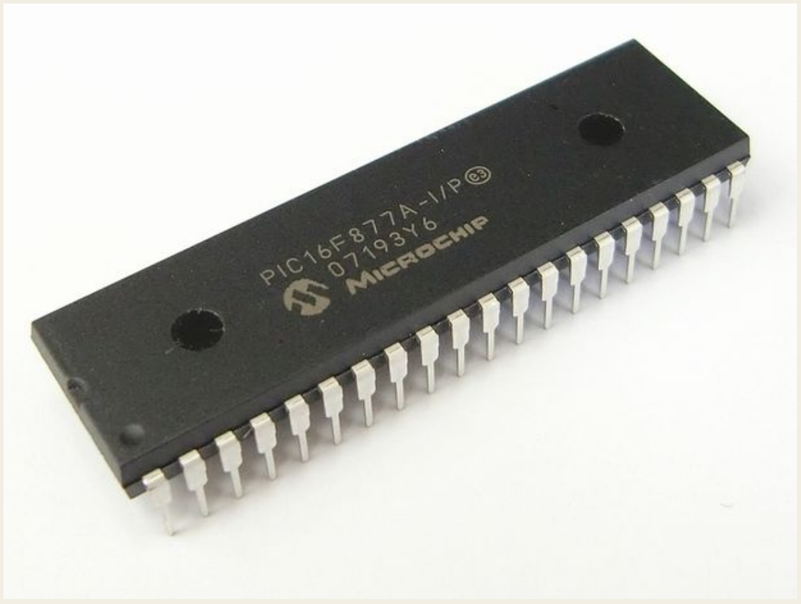


Obviously, one can use the 8051 microcontroller series as well to control the dimmer.
As I dont have an 8051 development system anymore, I cannot test any code, but should you want to develop this for an 8051, the following example may be of help:

```
//
//Controlling AC with a 8051
//Untested Code
//Compiles with MicroC Pro for 8051
int dimming;
int x;
int i;


void ex0_isr(void) iv IVT_ADDR_EX0 ilevel 0 ics ICS_AUTO {
/*===================================================*/
int dimtime=(75*dimming);
//delay_us(dimtime);
P0=0xFF; // sets entire PORT 0 high, can also use e.g. P0_1 =1 ;
delay_us(10); //propagationdelay
P0=0x00;
}

void delay(int maal){
for (x=1; x< maal; x++) {
delay_us(75); // 65 for 60Hz
}
}

/*===================================================*/
void main()
{

/*------------------------
Configure INT0 (external interrupt 0) to generate
an interrupt on the falling-edge of /INT0 (P3.2).
Enable the EX0 interrupt and then enable the
global interrupt flag.
-----------------------------------------------*/
IT0_bit =1; // Configure interrupt 0 for falling edge on /INT0 (P3.2)
EX0_bit = 1; // Enable EX0 Interrupt
EA_bit = 1; // Enable Global Interrupt Flag
P0 = 0x00; /ll pin of PORT0 declared as output

while (1)
{
for(i=5;i<128;i++){
dimming=i;
delay(10);/rbitrary delay between steps
}
}
}
```

I cannot garantee this code to work as I have no way of testing it. Should anybody try it and have results I would be glad to hear it.
An application note describing a fan control according to the same principle, can be found here.

Step 10: PIC Controlled lightdimmer: The software



If you want to use this circuit with a PIC microcontroller, the software in this link may help you get further:
http://www.edaboard.com/thread265546.html

A good article on zero crossing detection with a PIC can be found here:

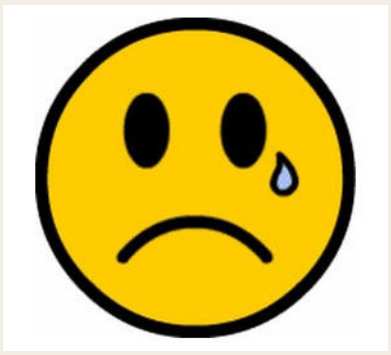
http://tahmidmc.blogspot.nl/2012/10/zero-crossing-...

The writer Syed Tahmid Mahbub gives a basic program that detects the zero crossing and then triggers the LED with a delay of 20ms .
Although I never worked with PIC's before and am no crack on C programming. I decided to see if i could build on his program and make it possible to vary the light intensity, rather than just give it one value (the 20ms delay).
I soon found out that the delay_ms and delay_us functions in C, are a bit tricky, namely that they don't accept a variable. The delay time needs to be known at the time of compilation as it is hard coded. I saw some complicated work-arounds, but I thought a simpler solution would be to make a function that gives a 75 uS delay (make that 65 for 60Hz) and call that with a parameter determining how often that delay is looped.
The maximum number of times the delay is looped is 128. That is because I have randomly chosen that the light should be dimmed in 128 steps (with 0 being full on and 128 being off).
A warning though: I have no PIC programmer and I am not planning (yet) to go into pics, happy as I am with the Atmega and Attiny series. Therefore I cannot test the program. I can only say that it compiles without problems, and if you want to use the circuit on a PIC, it will help you get started. You can also find full projects, including a program, here and here, including an IR remote and here

```
//------------------------------------------------------------------------------------------------------------
//Programmer: DIY_Bloke
//Strongly based on a 0-X program from Syed Tahmid Mahbub
//Compiler: mikroC PRO for PIC v4.60
//Target PIC: PIC16F877A
//Program for phase angle control
//zero crossing signal on pin 33 RB0/INT
//gating signal to MOC3021 via 220-470R from pin 19 RD0/PSP0
//X-tal 4 MHz
//------------------------------------------------------------------------------------------------------------
unsigned char FlagReg;
int x;
int maal;
int dimming=20;// '20' is just an example. Dimming should contain a
// value between 0 and 128 and can be taken from e.g. a
// variable resistor or LDR or a value coming out of a program
sbit ZC at FlagReg.B0;
void interrupt(){
if (INTCON.INTF){ //INTF flag raised, so external interrupt occured
ZC = 1;
INTCON.INTF = 0;
}
}
void delay(int maal){
for (x=1; x< maal; x++) {
delay_us(75); // 65 for 60Hz
}
}
```

```
void main() {
PORTB = 0;
TRISB = 0x01; //RB0 input for interrupt
PORTA = 0;
ADCON1 = 7; //Disable ADC
TRISA = 0xFF; //Make all PORTA inputs
PORTD = 0;
TRISD = 0; //PORTD all output
OPTION_REG.INTEDG = 0; //interrupt on falling edge
INTCON.INTF = 0; //clear interrupt flag
INTCON.INTE = 1; //enable external interrupt
INTCON.GIE = 1; //enable global interrupt
while (1){
if (ZC){ //zero crossing occurred
delay(dimming); // '20' is an example
PORTD.B0 = 1; //Send a pulse
delay_us(250);
PORTD.B0 = 0;
ZC = 0;
}
}
}
```

Step 11: Problems



If for whatever reason the circuit you built is not working, other than it starting to smoke.
Before you do any work on the circuit **UNPLUG IT FROM THE MAINS!!**

There are mainly 3 things that can happen:

1-The lamp is flickering
This is probably the most common problem you can encounter and there maybe several reasons for it e.g.
-a 'dirty' powersupply.
If your powersupply gives off a lot of extra spikes, these can be present on the 0X signal pin and mess up the clean Zero crossing signals. Try another powersupply.
-'timing' problems
using an optocoupler gives a precise zero-crossing signal, but it is not extremely narrow. The pulse width of this circuit (at 50Hz) is typically around 600us (0.6ms) which sounds fast enough. The problem is that at 50Hz each half cycle takes only 10ms (8.33ms at 60Hz), so the pulse width is over 5% of the total period. This is why most dimmers can only claim a range of 10%-90% - the zero crossing pulse lasts too long to allow more range. The solution is to avoid regulating all the way down or all the way up. Also increasing or sometimes decreasing the step-value (the number 75 for 50Hz and 65 for 60Hz) may cure that.

2-The lamp is constantly on
This might be a software or a hardware problem and the easiest way to sort that out is to make sure the microcontroller is not connected to the circuit. If the lamp is still on there are grossly 4 possibilities:
-You somehow fucked up the circuit, check if it is indeed OK and that everything is connected to where it shoudl be connected.
-The MOC3021 is somehow receiving a positive input, make sure there are no stray drops of solder shorting things that shouldn't be shorted. Short the input and ground wire and see if the lamp stays off.
-The MOC3021 is short circuited at the high voltage end. Remove the MOC3021 from its socket and see what happens: if yr lamp stays off there is likely something wrong with yr MOC3021. If your lamp stays on, you probably have a faulty TRIAC
-You have a faulty TRIAC. As described above. Yet, check the gate resistor if it really has the correct value, just to make sure

3-The lamp is constantly off
As this may also be a software or hardware problem, first see what hapens with the arduino disconnected.
Connect the input to a plus 5Volt supply and measure the voltage on the primary side of the optocoupler (YOUR CIRCUIT SHOULD NOT BE CONNECTED TO THE MAINS). If that is a couple of volts, connect your circuit to the mains and see what happens. If the lamp switches on there is a problem with the input signal. If it stays off, you may have a faulty optocoupler, a faulty TRIAC or your circuit somehow is not connected to the mains. Another possibility is that the voltage drop over the LED is preventing the optocoupler to open, especially when you are using say 3.3 V as a driving voltage. Make sure you have an LED with a low voltage drop or replace it by a wire bridge.

A piece of code that can help you test the Triac circuit is to add the following into the setup

```
void setup()
{
pinMode(AC_LOAD, OUTPUT); // Set the AC Load as output
for (int i=0; i < 10; i++) {
digitalWrite(AC_LOAD, HIGH); // triac firing
delay(1000);
digitalWrite(AC_LOAD, LOW); // triac Off
delay(1000);
}
}
```

This will first fire the TRIAC a few times so you can see it is working

Most common fault till now

From all the people that contacted me about problems of the circuit not working, the most common fault was: faulty wiring: a chip put upside down, a solder joint not good, a wire not connected right.

Step 12: The gate resistor: a bit of theory

When cruyising the internet for Triac switches, you may have come across a large diversion in the value of the gate resistor value. My choice usually is to take the lowest value that will still protect the gate and the optocoupler.
Reader Mali Lagunas did some research in the theory behind the criteria to choose the value of the gate resistor. Which i will copy below:

The resistor when placed in this circuit, will have two main effects:
a) It will limit/provide the current going into the gate of the triac (I_{GT})
b) It will cause the voltage to drop when the triac is on (V_R)

The lowest value this resistor may have (for 220 V AC) is R=220*sqrt(2)/I_{TMS}, where I_{TMS} is the maximum peak current allowed in the photocoupler's phototriac. These are surge values, thus they are transient and account for a limit before breakdown. Therefore in your circuit R would be R=220*sqrt(2)/1=311.12 or 330 ohms, since the MOC3021's I_{TMS}=1A. This is consistent with I_{GM} which is the peak gate current of the TIC206. In your schematic you use 1K which would limit the current to 311mA.

This "surge" case may take place only when a pulse is received by the phototriac and it is able to conduct I_{GT}, and of course for a line value of 220*sqrt(2). Charge will then accumulate in the triac's gate until V_{GT} gets build up and the the triac gets activated.

In quadrant I, (V_{GT} and A1 are more positive than A2) in order for sufficient charge to build up and V_{GT} in the main triac to bee reached, the voltage across the triac must equal V_R+V_{TM}+V_{GT}
Of course V_R=I_{GT}*R . Commonly, V_{TM}+V_{GT} will both account for approximately 3V (datasheet). At the same time, the resistor must provide sufficient current to the Triac's gate, let's say a minimum of 25 mA (sensitivity of the Triac), thus

V_{triac}= 330ohms*25mA+1.3V+1.1V=10.65V and
V_{triac}= 1k-ohms*25mA+1.3V+1.1V=27.4V (the value in your circuit)

Which is the voltage needed to activate the triac. Therefore, the smaller the resistor the less voltage is required to switch on the main triac. What goes on afterwards is mainly that there is a voltage drop across A1 and A2 and therefore the phototriac voltage and current will drop causing turn-off state (of the phototriac). The main triac will be kept switched on if the holding current I_H is respected. When the load current is below I_H, the main triac is switched off until a pulse from the photodiode is emitted again in order to polarize V_{GT} and build the required charge in the next cycle. Q1 and Q3 are the quadrants for this setup.

Step 13: Dimming: A bit of Theory

Just as a background to this instructable: There are various types of dimmers. What is presented here is a phase-controlled (aka 'phase-cut') leading edge (aka "forward phase")TRIAC dimmer.

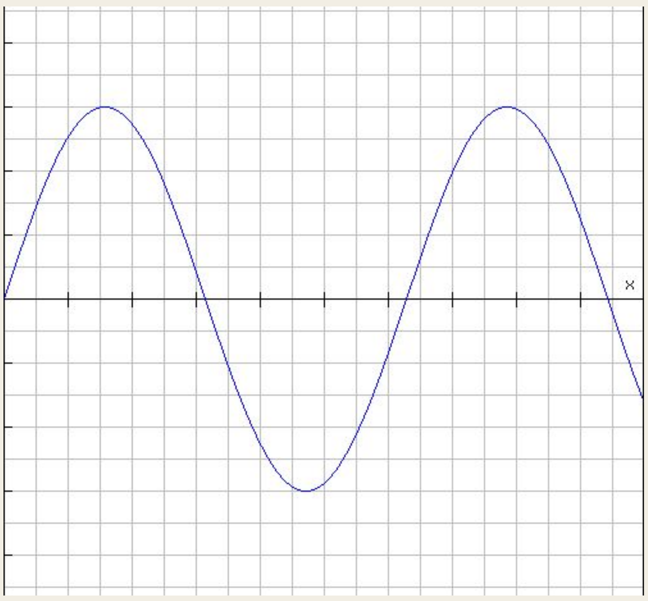
Leading Edge Dimmers
In this type the dimmer actually cuts parts off the beginning of the sinewave. This is the most widely used type of dimmer as it is ver suitable for TRIACs. After all, A Triac is easy to switch on and it will switch off by itself once there is a zero crossing because the current drops below the gate hold current

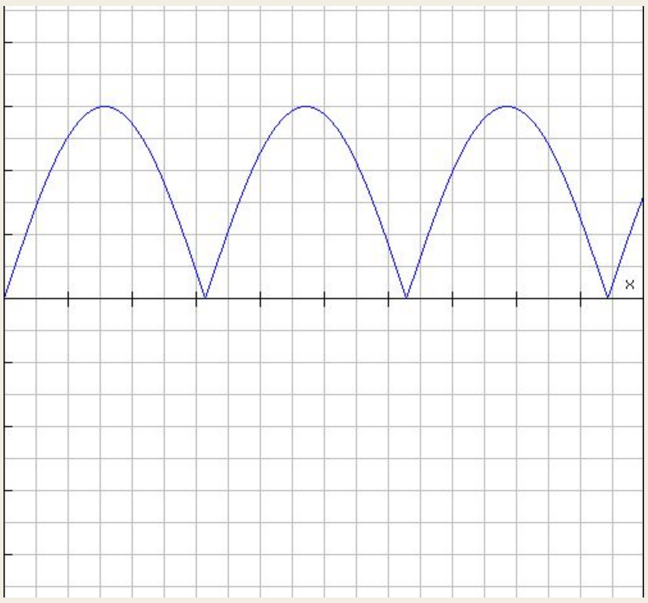
Trailing Edge Dimmers
Also known as 'reverse phase control' dimmers. A trailing edge dimmer is a considerably more complex circuit. The simple circuitry that is common with leading edge types can no longer be used, because most TRIACs cannot be turned off. Gate turn-off (GTO) TRIACs exist, but are far more expensive and less common in the relatively small sizes needed for lighting. To be able to implement a trailing edge dimmer, the switching device must turn on as the AC waveform passes through zero, using a circuit called a zero-crossing detector. After a predetermined time set by the control, the switching device is turned off, and the remaining part of the waveform is not used by the load.

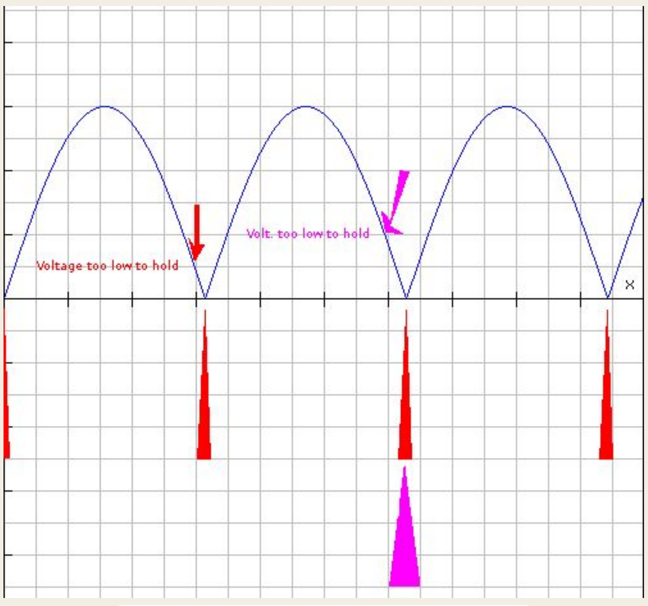
Trailing edge dimmers commonly use a MOSFET, as these require almost no control current and are rugged and reliable. They are also relatively cheap and readily available at voltage ratings suitable for mains operation. Another option is to use an IGBT (insulated gate bipolar transistor), which combines the advantages of both MOSFET and bipolar transistor. These are generally more expensive than MOSFETs. Again, the waveform is ideal, and it is obvious from the actual waveform shown in Figure 9 that there is a significant deviation - especially at full power. This is caused because some of the applied voltage will always be lost because the complex electronics require some voltage to operate.

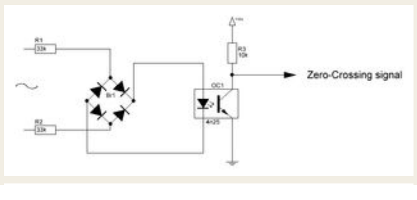
Most trailing edge dimmers have another useful function - at least when used with incandescent lamps. The circuitry is designed to provide a 'soft start', increasing the voltage to the lamp relatively slowly. With incandescent lamps, this almost eliminates 'thermal shock' - that brief period at switch-on where the lamp draws around 10 times the normal operating current. Thermal shock is responsible for most early lamp failures - it is rare indeed for any incandescent lamp to fail while it's on. Failure is almost always at the moment the switch is turned on. By including the soft-start feature lamp life is increased.

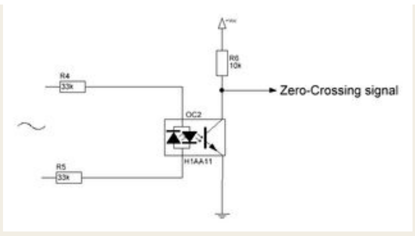
Step 14: Zero Crossing: a bit of theory

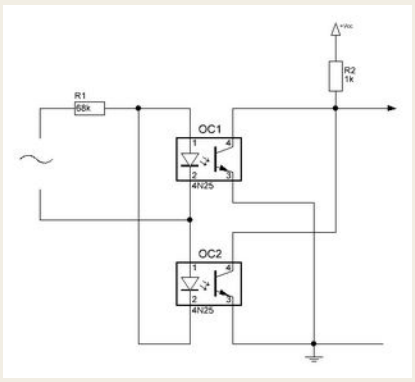


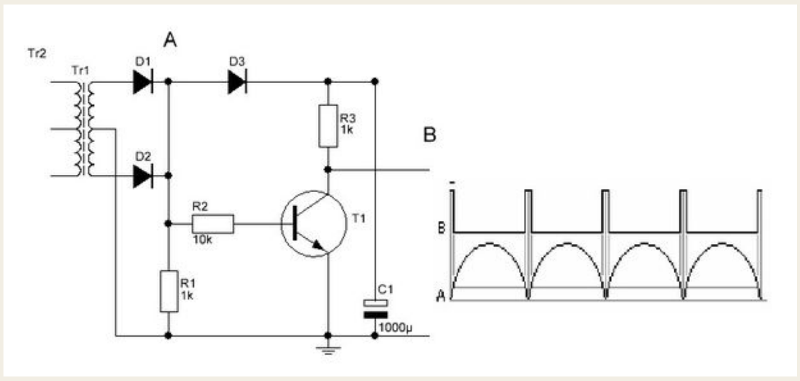


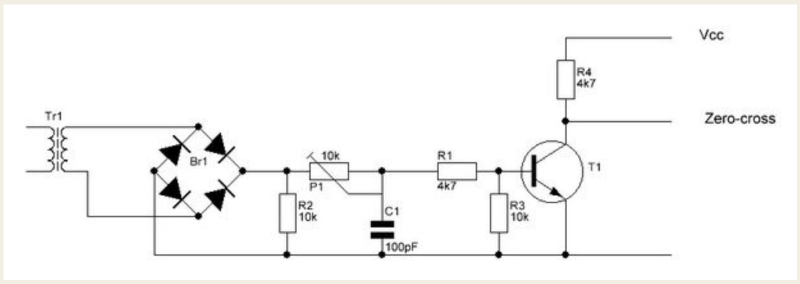












Though I described the zerocrossing already, I will spend some more words on it.
With the 'bridge and opto-coupler' circuit that I used in this project, the principle is very clear: A mains AC voltage passes through 2 resistors of 33k and is rectified by the diode bridge.
This rectification results in a pulsating DC voltage that keeps the optocoupler open, keeping the zerocrossing signal LOW till the voltage drops to 'zero' at what point the optocoupler will not be in conduction anymore and the zerocrossing signal is pulled high, untill the voltage rises again enough to send the optocoupler into conduction again, resulting in the zerocrossing pin going LOW.
The 'quality' of that zerocrossing pulse is of course depending on a number of factors but mainly on the speed of the optocoupler, the value of the collector resistor, but not in the least on the value of the two resistors in the mains line.

If that value is too low, your optocoupler will burn out, but if it is too high, the voltage at which there still is enough current going through the optocoupler to keep it conducting becomes higher and higher. That means that if the resistor value is too high, the switching of the optocoupler will happen higher on the rising and descending flank of the sin wave, resulting in a wide zerocrossing signal, that starts way before the actual zerocrossing until way after the zerocrossing.
Ergo: The resistor value should be as low as possible. In practice however I found the 2x 33k to be a good value, leading to a pulse starting abt 200uS before the actual zerocrossing. That is very acceptable. The current through the 4N25 is approximately 3.33 mA. Surely we could take that up a notch, but it isn't necessary. With these values the idle use of this circuit is an estimated 0.7 Watts

The same actually goes for the circuit with the H11AA1. The advantage of the H11AA1 is that one doesn't need a diode bridge as it has two antiparallel diodes. The same goes for the IL250 series or the LTV814
One can reach the same effect with two regular optocouplers such as the 4N25, as the figure shows or with a dual optocoupler.

I also provided a circuit in which the width of the zerocrossing pulse can be regulated.
As said before, the width of the Zerocrossing signal determines how far before the actual zerocrossing the interrupt is generated. Ideally, if you know how wide your zerocrossing signal is, you could take that into account in the software. Suppose your signal is 600uS wide and suppose that is a evenly divided timing. Then you know that your interrupt is generated some 300uS before the actual Zerocrossing. You could wait that period after each interrupt to get a more precise handling of the zerocrossing