



**Design Stellaris 2006 Contest  
Project Number LM1633  
Luminary Micro Component LM3S811  
Abstract**

## **Uninterruptible Solar Power Supply**

The gradual warming of our planet due to man-made pollution is a topical issue. There are record high levels of greenhouse gas emissions, and 20% of these gas emissions can be attributed to residential energy use<sup>1</sup>. One component of residential energy is the power used by standby loads, such as answering machines and cordless phones. The plug pack used to power such devices runs 24 hours a day, 7 days a week, consuming a small but constant amount of energy. Over a year, this figure can add up to a surprisingly significant amount of energy, for example 27kWh for the typical answering machine<sup>2</sup>. This equates to roughly 27 metric kilograms (43 lbs) of CO<sub>2</sub> gas generated from a coal-fired power station.

The uninterruptible solar power supply is intended to take these small standby loads off the grid, and power them directly from solar panels. The supply acts as an uninterruptible power supply (UPS), switching seamlessly back to the grid if the solar power is unavailable during the night or cloudy weather.

One advantage of using a solar-powered UPS is that it bypasses the usual regulatory requirements imposed by utilities on grid-interactive solar power systems, as the solar panels are never directly connected to the grid. Another advantage of focusing on powering only standby loads is the system cost is kept low, requiring in most cases only a single solar panel. The device is shown working below supplying a 40W globe.



**Photo 1. Solar UPS powering a 40W globe**

The Solar UPS design is shown in the diagram below and consists of three main system components: the Inverter & Control components and the AC Switchgear component.

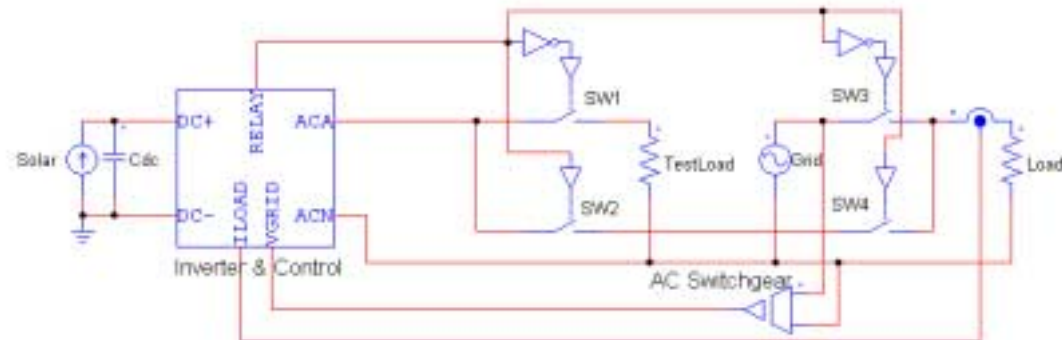


Figure 1. Solar UPS System Diagram

The Inverter component is responsible for converting the low DC voltage from the solar panel to single-phase AC sine wave, which can then be used via a transformer for supplying the standby loads. The circuit is designed to switch currents of less than 3Adc to a maximum voltage of 30Vdc.

The AC Switchgear component is responsible for routing AC power to the load from either the inverter or grid, as well as monitoring of the grid frequency & phase and the load current. The switchgear also connects a test load to the output of the inverter when the grid is connected to the load, so the amount of available solar energy can be measured by loading the inverter output.

The Control component is at the heart of the system, and coordinates the Inverter and AC switchgear. The Luminary Micro LM3S811 controller provides a compact solution, as it has good motor-drive support and can drive the inverter signals directly. It also has a 32-bit ARM core with a FIFO capable ADC, suitable for implementing the DSP core of the inverter control. The core control interrupt is shown in the following sample Keil-C listing:

```
//
// The interrupt handler for the ADC triggered inverter control interrupt.
// This runs at 20kHz and uses <20% of CPU resource (24MHz operation).
//
void ADCIntHandler(void) __irq
{
    SWord16 duty;
    SWord32 temp;
    char zx_flag;

    // Clear the ADC interrupt.
    ADCIntClear(ADC_BASE, 0);
    // Read the data from the ADC FIFO
    ADCSequenceDataGet(ADC_BASE, 0, ulADC);

    // Integrate the AC channel measurements for approximate RMS calculations
    temp = ulADC[CHAN_LOAD_AMPS] - dc_offsets[CHAN_LOAD_AMPS];
    if(temp < 0) temp=-temp;
    sum_abs[CHAN_LOAD_AMPS] += temp;
    temp = ulADC[CHAN_INV_AMPS] - dc_offsets[CHAN_INV_AMPS];
    if(temp < 0) temp=-temp;
    sum_abs[CHAN_INV_AMPS] += temp;
    temp = ulADC[CHAN_VAC] - dc_offsets[CHAN_VAC];
    if(temp < 0) temp=-temp;
    sum_abs[CHAN_VAC] += temp;
    sum_cnt++;

    // Generate AC waveform if we are switching
    if(HWREGBITW(&g_ulFlags, FLAG_SWITCHING))
    {
        // advance NCO phase as a fixed point fraction
    }
}
```

```

index += index_step;

// extract sample lookup index
indexb = (index >> 16) & 511;

// determine output duty cycle
temp = ((SWord32)sinlut[indexb] * vac_gain) >> 15;
duty = (SWord16)temp;

// determine output standing phase
if(indexb & 256)
{
    // clip to minimum duty
    if(duty > -MINIMUM_DUTY)
        duty=-MINIMUM_DUTY;

    // standing phase transition?
    if(HWREGBITW(&g_ulFlags, FLAG_NCOPHASE))
    {
        HWREGBITW(&g_ulFlags, FLAG_NCOPHASE)=0;
        // set up standing phase output
        HWREG(PWM_BASE + PWM_GEN_1_OFFSET + PWM_O_X_GENA) =
            ((PWM_GEN_ACT_ONE << PWM_GEN_ACT_A_UP_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_DN_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_ZERO_SHIFT) |
             (PWM_GEN_ACT_ONE << PWM_GEN_ACT_LOAD_SHIFT));

        HWREG(PWM_BASE + PWM_GEN_0_OFFSET + PWM_O_X_GENA) =
            ((PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_UP_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_DN_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_ZERO_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_LOAD_SHIFT));

    }

    // load duty cycle
    HWREG(PWM_BASE+PWM_GEN_1_OFFSET+PWM_O_X_CMPA) = (Period + duty) >> 1;
}
else
{
    // clip to minimum duty
    if(duty < MINIMUM_DUTY)
        duty=MINIMUM_DUTY;

    // standing phase transition at zero degrees?
    if(!HWREGBITW(&g_ulFlags, FLAG_NCOPHASE))
    {
        HWREGBITW(&g_ulFlags, FLAG_NCOPHASE)=1;
        // indicate zero crossing event
        zx_flag=1;
        // set up standing phase
        HWREG(PWM_BASE + PWM_GEN_0_OFFSET + PWM_O_X_GENA) =
            ((PWM_GEN_ACT_ONE << PWM_GEN_ACT_A_UP_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_DN_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_ZERO_SHIFT) |
             (PWM_GEN_ACT_ONE << PWM_GEN_ACT_LOAD_SHIFT));

        HWREG(PWM_BASE + PWM_GEN_1_OFFSET + PWM_O_X_GENA) =
            ((PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_UP_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_DN_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_ZERO_SHIFT) |
             (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_LOAD_SHIFT));

    }
    else
        zx_flag=0;

    // load duty cycle
    HWREG(PWM_BASE+PWM_GEN_0_OFFSET+PWM_O_X_CMPA) = (Period - duty) >> 1;

    // process zero crossing event
    if(zx_flag)
    {

```

```

// average sample measurements over the last line cycle, and reset accumulators
if(sum_cnt)
{
    temp = sum_abs[CHAN_LOAD_AMPS] / sum_cnt;
    sum_abs_latched[CHAN_LOAD_AMPS] = (Word16)temp;
    temp = sum_abs[CHAN_INV_AMPS] / sum_cnt;
    sum_abs_latched[CHAN_INV_AMPS] = (Word16)temp;
    temp = sum_abs[CHAN_VAC] / sum_cnt;
    sum_abs_latched[CHAN_VAC] = (Word16)temp;
    sum_cnt=0;
    // reset accumulators
    sum_abs[CHAN_LOAD_AMPS]=0;
    sum_abs[CHAN_INV_AMPS]=0;
    sum_abs[CHAN_VAC]=0;
}
// run the outer inverter control
ControlLoop();
}
}
else
{
    // Drive both bottom switches ON if not switching
    HWREG(PWM_BASE + PWM_GEN_1_OFFSET + PWM_O_X_GENA ) =
        ((PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_UP_SHIFT) |
        (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_DN_SHIFT)|
        (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_ZERO_SHIFT) |
        (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_LOAD_SHIFT));

    HWREG(PWM_BASE + PWM_GEN_0_OFFSET + PWM_O_X_GENA ) =
        ((PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_UP_SHIFT) |
        (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_A_DN_SHIFT)|
        (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_ZERO_SHIFT) |
        (PWM_GEN_ACT_ZERO << PWM_GEN_ACT_LOAD_SHIFT));
}

// Increment the clock ticker used for timing
ticker++;
}

```

### Solar UPS Schematics

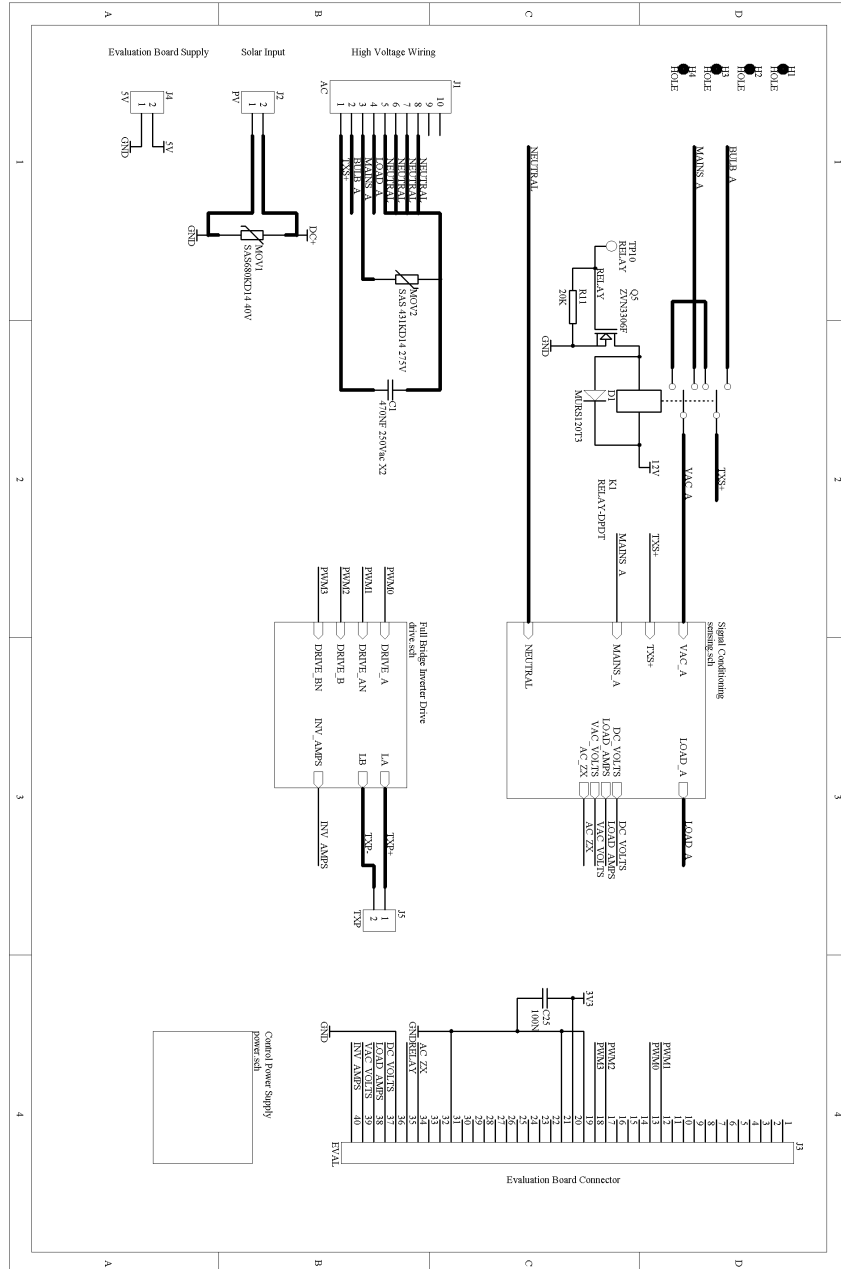


Figure 2. Schematic showing System Interconnections

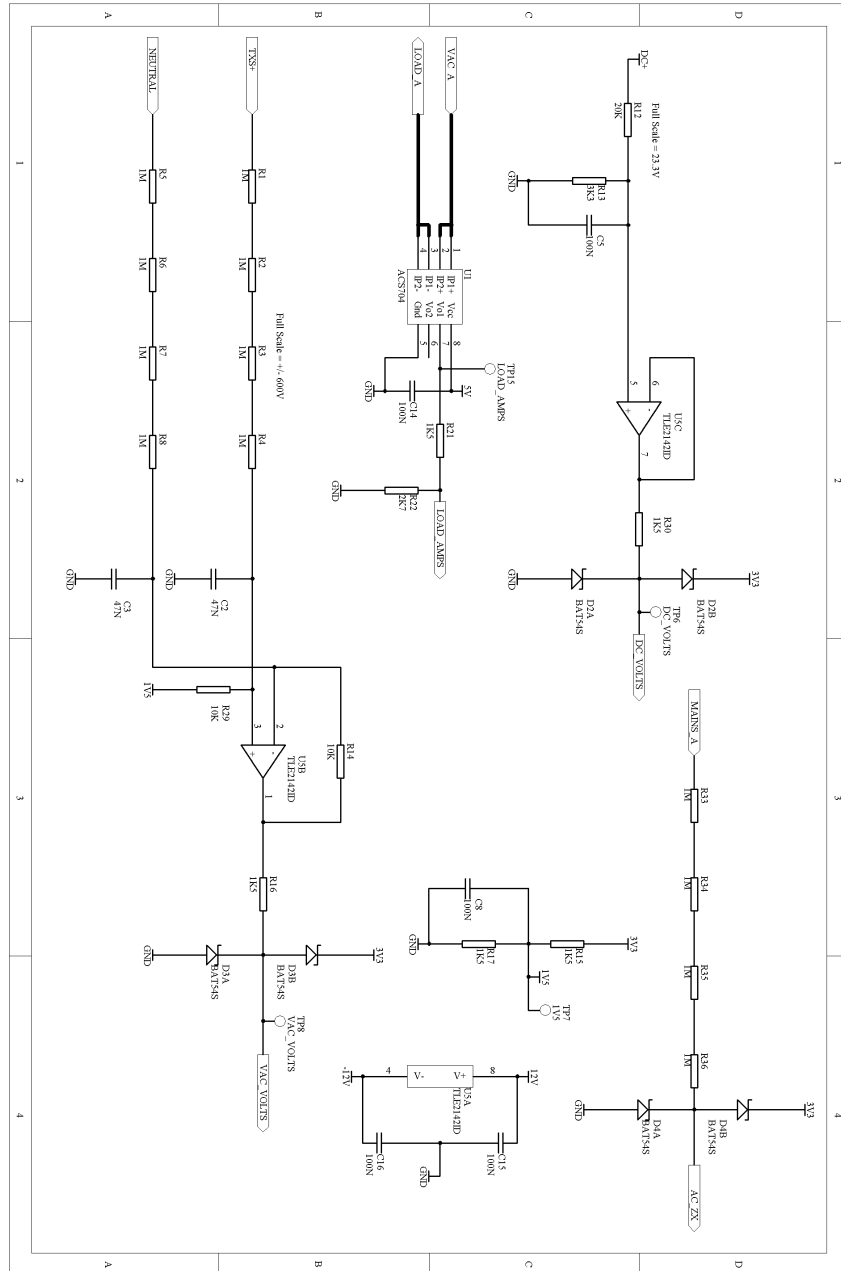


Figure 3. Signal Conditioning Schematic

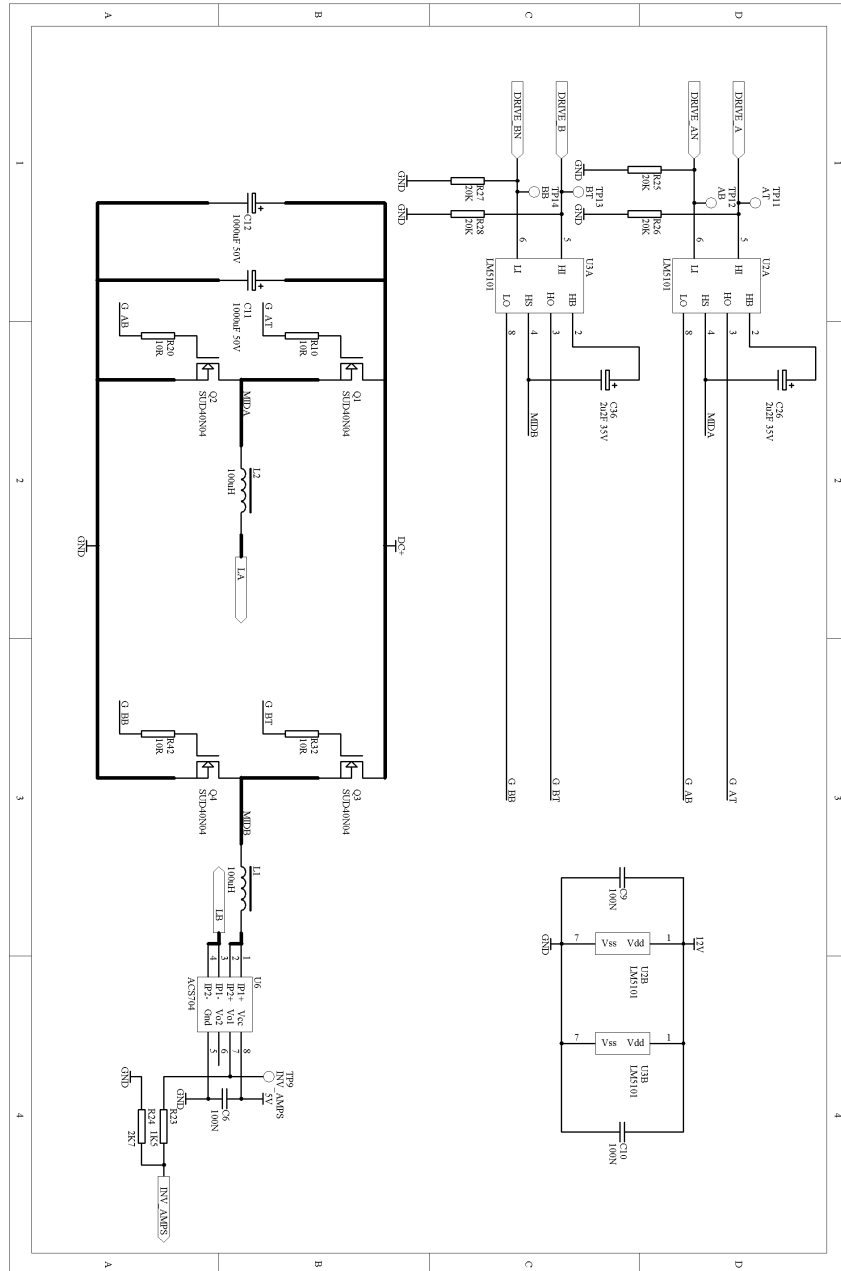


Figure 4. Inverter Full Bridge Schematic

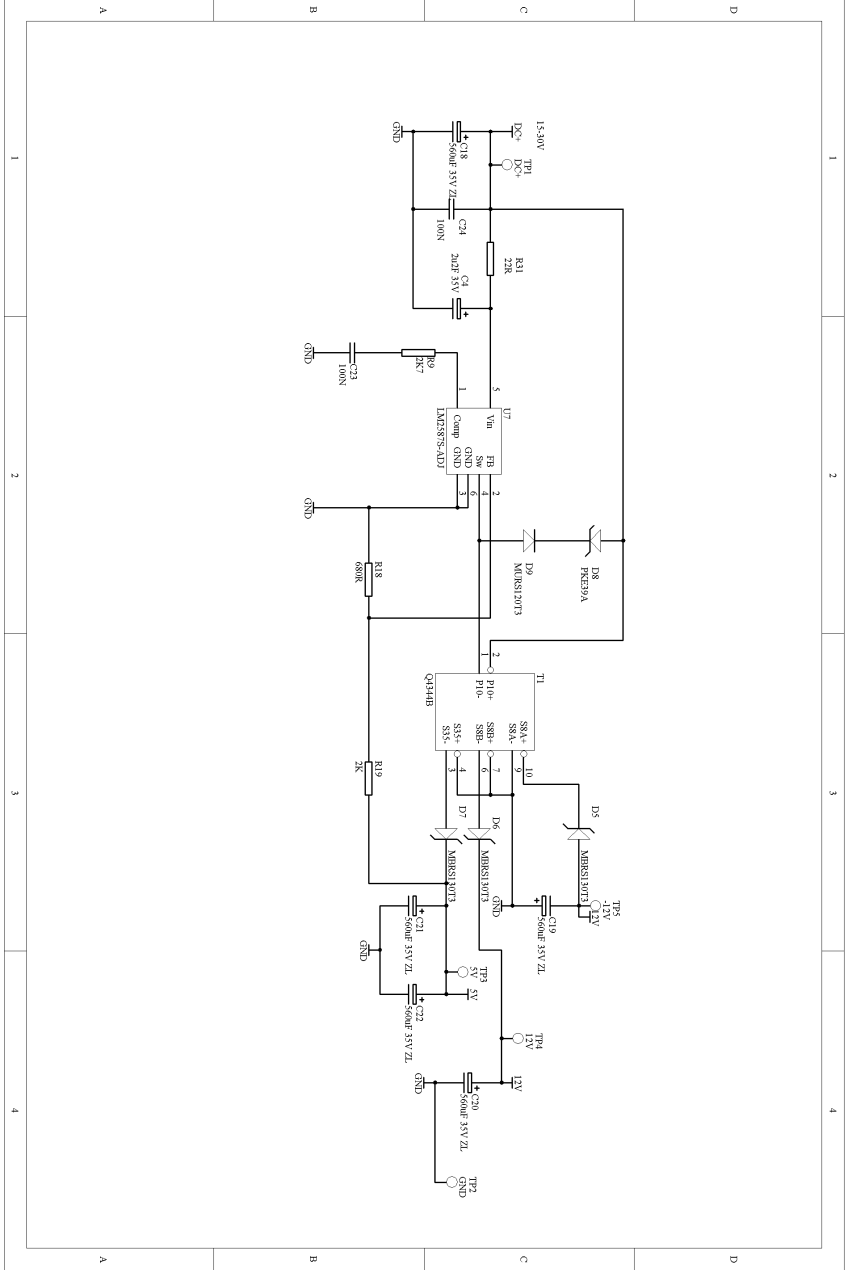


Figure 5. Control Power Supply Schematic



## References

[1] "Emissions of Greenhouse Gases in the United States in 2005". Energy Information Administration. <http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html>

[2] "Proposal from the U.S. Environmental Protection Agency to the North American Communications Environmental Excellence Initiative and the Center for Resource Management". Environmental Protection Agency.

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