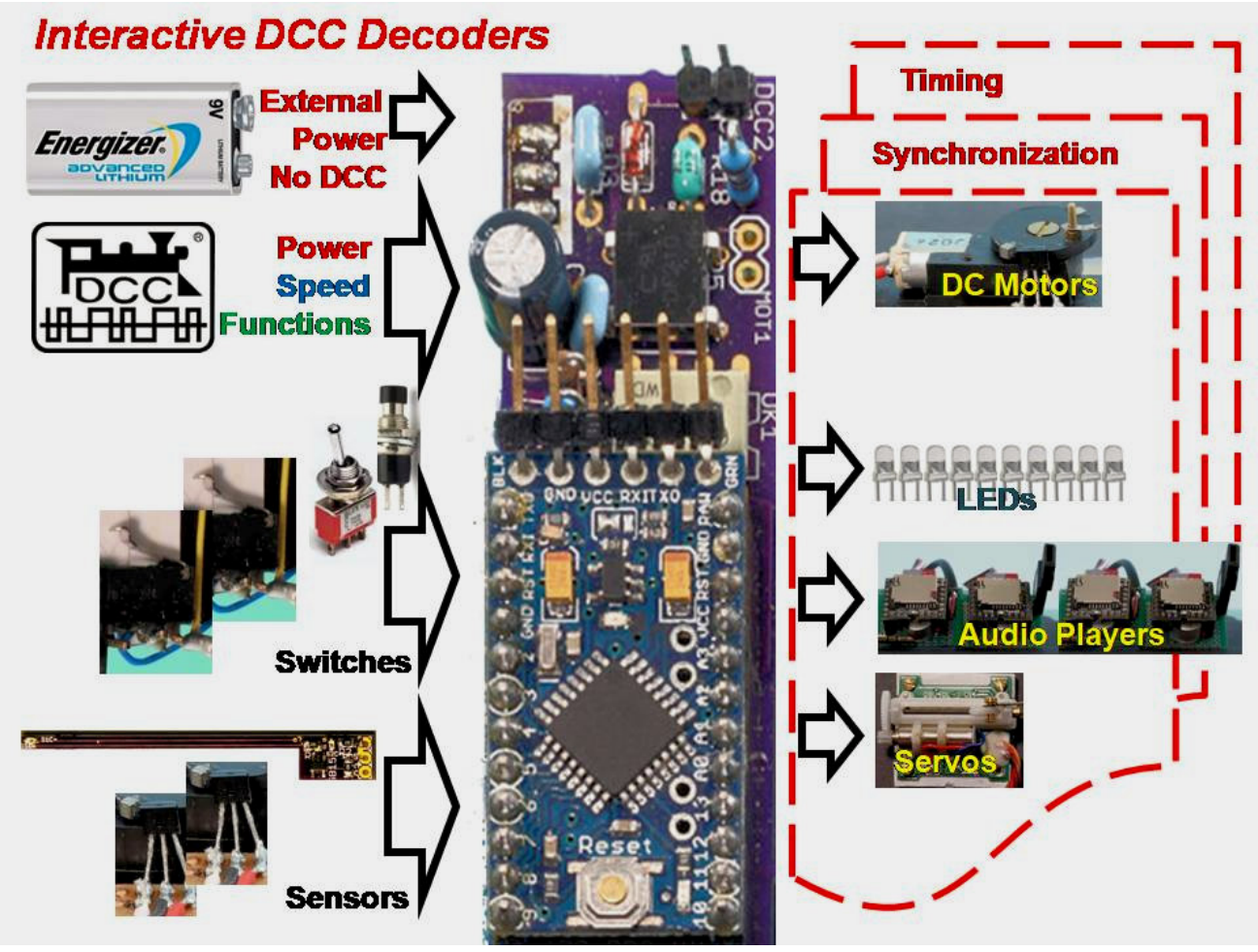
Interactive DCC Decoders IDEC The Next Generation v1.08

Scale **M**odel **A**nimation—bringing models to life—adds enormously to the interest and enjoyment of any layout or individual model! When I started out designing low-cost decoders, they were intended to facilitate my animation work. With the encouragement and interest from many modelers, these grew into a set of over 19 preconfigured decoders. This introduces a new generation of decoder – **DCC decoders with many inputs**, allowing you and your layout to **interact** with your decoders. The series of Interactive Decoders (**IDEC**) were designed as an integral part of my animation work, but the inventive modeler can apply them to a wide variety of projects. The initial library of 13 decoders combine external switch and DCC function control of lighting, sound, and movement, with relatively sophisticated internal timing. They are operable and configurable via DCC, but can work independently, without a DCC connection. IDEC decoders can be loaded onto the same hardware described in **SMA20 Low Cost 17 Channel DCC Decoders Ver 6.01 with Sound,Triggered Sound,Stepper,Dual Motor,LED and Servo Control** https://model-railroad-hobbyist.com/node/24316 . I have been using these for some time, but I don't think I have exercised even half of their capabilities. Have a look yourself. The following article is representative of the **IDEC Version 1.08** release. A more comprehensive description of the IDEC library can be found here: **SMA35 Interactive DCC Decoders IDEC The Next Generation - Sequencing Movement Sound & Lighting** **https://model-railroad-hobbyist.com/node/40940**

Interactive Decoders – An Introduction to a New Generation



IDEC decoders give modelers abilities to sequence motion, sound and light. They can be configured, started, and controlled by multiple external sensors, external switches and/or by DCC functions. These could be applied to moving vehicles, signs, locomotives, trolleys, doors, bridges, buildings, and anything that might require sequencing and coordination of motor drives, servos, sound, LEDs, relays, and lighting. These do not solve all such modeling problems, but they can help you do some interesting things. These videos offer a small sample:

https://youtu.be/KnUr6hjzbh8 IDEC-1: Introduction, Timing, Motor Control and Sensors
https://youtu.be/gYobhfVO7_E IDEC-2: Lighting Control and Sound Sets
https://youtu.be/zvvosubqdp8 IDEC-3: Motor Timing with Sensors and Sound

Interactive Decoders

Finally, there is an accompanying article: **SMA36 Interactive DCC Decoders (IDEC's) Principles of Operation** http://model-railroad-hobbyist.com/sites/model-railroad-hobbyist.com/files/users/geoffb/newSMA36article where even more technical details and comments for those brave souls that long for the mental challenge of enhancing these beyond their present capabilities, and need some semblance of understanding of the 12,000+ lines of code.

Making Decoders Listen to the World: An Introduction to the Next Generation

The IDEC decoders exhibit some interesting characteristics that are a bit different:

--They have multiple external switch inputs **directly** to the DCC decoder which control its operation
--They combine both decoder DCC function controls and input switches in a defined, predictable manner
--They have a master disable for the entire decoder
--They can be powered directly from DC (+5 or +12 Volt power) to operate independently of any DCC bus
--They can be set up to operate on power up, independent of any DCC commands
--They have programmable CV variables which can be accessed dynamically (with immediately visible results) as a mobile decoder and then operate independently of a DCC bus, different from the SMA20 series
--They combine interactive motor control, playing selected sound tracks, and lighting control
--They can switch LEDs/pins, combinations of pins, set servos, and play audio tracks
--Some decoders can support 1,2,3 or 4 audio players, each with 2 channel, near stereo quality sound
--Some decoders support up to 10 independent, non-interfering timing chains of differing events
--An **IDEC Sound Set decoder** can play up to 10 sound sets simultaneously with **independent** timing, each with 5 groups of CV controlled timing delays (from 1/1000 of a second to 255 minutes – 4 hours 15 minutes), independent volume control, and a selection of 254 sound tracks; each sound set can directed to 1-4 players, or a random track can be selected at any time from a specified group of tracks
--An **IDEC Switching Set decoder** can run up to 10 Switch sets simultaneously with independent timing, each with 5 groups of CV controlled timing delays (from 1/1000 of a second to 255 minutes – 4 hours 15 minutes), with independent parameterized commands, controlling any of 8 Switch pins, by single pin or in groups, with direct, random, weighted random, alternating pairs, with sound generation, servo control, and daisy chaining switch sets to create up to a timed chain of 45 controlled events

--An **IDEC Large Switching Set decoder** can run up to 2 Switch sets simultaneously with independent timing, each with 25 groups of CV controlled timing delays (from 1/1000 of a second to 255 minutes – 4 hours 15 minutes), with independent parameterized commands, controlling any of 8 Switch pins, by single pin or in groups, with direct, random, weighted random, alternating pairs, with sound generation, servo control, and daisy chaining switch sets to create up to a timed chain of up to 49 controlled events
--A user switch can enable the listing of most all configurable CVs to the serial connection on power up

At present, you can choose from a library of 13 predefined decoders and functions which do **not** require your programming to use, each of which can be further configured via typical, DCC programmable CV's. I have also included an additional folder, **"IDECDemo&Diags"** which includes an additional 10 sketches I used to develop the demos in the videos and diagnostic routines I use to test servos and DFPlayer sound modules. Unlike some of the SMA20 decoders, these have been designed so that changing configuration CVs will take effect **immediately**. For example you can set the end transit points of a servo via CV and immediately see the effect on the servo. You can change the volume setting of an audio track and hear the difference it makes, etc. Each decoder has a decoder master disable function which can be used to control turn on and turn off for day/night sequencing. Key decoder functions are controlled by **both** DCC function setting for the decoder and switch inputs directly to the decoder from panel switches, sensors, car detectors, etc. A DCC function ON enables a feature OR setting a switch input LOW enables a feature. When BOTH the respective DCC function is OFF AND the respective Switch input is HIGH, then the feature is disabled. ALL combination functions operate this way – by definition. As with the SMA20 decoder series before, all SMA35 decoders in the library can be download here: **http://www.scalemodelanimation.com/Decoders/NmraDcc-IDEC.zip**
If you already have a NmraDcc library in your …\Documents\Arduino\libraries\ folder you need to delete it and replace it with your unzipped NmraDcc-IDEC library.

There is an important underlying issue, which very few modelers have ever really caught on to: the DCC bus I use to feed these in **not** the same DCC bus I use to control trains. It is a separate, high power (15 Amperes plus) feed around the layout – with no exposed wiring – **none**. Hence the probability of shorts is generally limited to my clumsiness, not train operation. Remember, DCC is set of command signals **carrying** power. This is great if one is naturally lazy and doesn't want to string hundreds of wires around your layout. You feed the 2 DCC bus wires to decoders like the IDEC's and let them do the work locally. Configuration can be done remotely, and control can be either remote or local, in an orderly, pre-defined manner. The update outlined in SMA34 More Power to SMA20 Decoders with Tips and Additions https://model-railroad-hobbyist.com/node/39306 allows these decoders to source up to 2 Amperes of power without heat sinking. This was a precursor to, and motivated by using the IDEC decoders, all by design intent. None of this prevents the modeler from using the IDEC decoders with any NMRA DCC compatible system. They **are** compatible.

Have Fun! ☺
Best regards,
Geoff Bunza

Sequencing, Sound Sets, and Switch Sets

Good animation has elements of movement, lighting, sound, sequencing or synchronization, and story. The IDEC decoders handle many, but not all, sequencing issues for scale model animations. The controlled motor Drive in IDEC1_1_MotSound5Led is a relatively simple, and useful example, allowing for movement (via DC motor) to be controlled by sensors embedded in the model. Running a forklift, trolley or shuttle back and forth with stops becomes easy. Timing delays at each point can be set, together with sounds for door openings, announcements, brakes, motors, etc. The combination controls the sequencing for all the activities.

The Sound Sets and Switching Sets described next are derived from the concept of timing wheels and timing chains in the commercial, electronic system simulators I worked with for many years. Here, they enable each timing chain to literally operate independently. For example, one can set up Sound Set 1 playing the first movement of a Bach Sonata, wait for 10 minutes and play a Mozart concerto. Simultaneously, one can start Sound Set 2 waiting 5 minutes, play Led Zeppelin's Stairway to Heaven on the **same** audio player (at a different volume level of course), wait 50 minutes, go to max volume, play AC/DC Thunderstruck, and terminate. The net effect would be heard as Bach, Led Zep, Mozart, and when you were least expecting it… be Thunderstruck!

Playing high quality sounds can be facilitated by sequencing too. The DFPlayer sound module (https://www.amazon.com/dp/B07T8CTKK6/ref=dp_cerb_2) I use is low cost (typically a few dollars), programmable, supports a 16GB on-board SD Memory card, is small, and can generate reasonable quality audio with its on-board 3 Watt mono amplifier, or near CD audio quality with an external amplifier. The best part, I discovered, is that it only requires **one** signal line from the Arduino to operate (together with +5 Volt power and ground). Once a command is send to the DFPlayer, it will operate independently of the Arduino until it completes the command. A group of **three** elements: a delay (from one millisecond to 255 minutes), an optional volume setting, and a designated sound track (file on the SD Memory card on the DFPlayer) describe one sound "**event.**" Events compose a chain of sound events called a **sound set**, defined as a set of 5 events. Delays set in each event can account for long sound tracks in play. Sound tracks are individually played until they either end, or another track is specified for play, which stops the first and starts the second track immediately. Sound sets are started by DCC functions or external switches or sensors. Sound tracks can be randomly chosen. Multiple Sound Sets can be chained together to form long chains of Sound Sets. **IDEC3_2_2SoundPlyrs, IDEC3_3_4SoundPlyrs,** and **IDEC4_3_ServosLEDsSounds3Plyr** can direct sound play to 2, 3 or 4 different sound players.

Sound Sets change to Multifunction ***Switching Sets*** in both **IDEC2_4_FunctionSets** and **IDEC2_5_LargeFunctionSetsDev** decoders. "Events" are still composed of three elements. Event triples include a similar delay as in sound sets, a mode or command specifying differing actions, and a parameter which usually denotes a output pin or pins for the action to occur. Actions include setting digital pins on/off, on/off randomly, on/off weighted randomly, playing sound tracks, setting servo position, controlling multiple pins (such as for alternate blinking), and chaining switch sets. Switch Sets are controlled by DCC functions or external switches or sensors. The IDEC2_4_FunctionSets decoder employs ten, 5 event Switch Sets. DEC2_5_LargeFunctionSetsDev decoder uses two, 25 event Switch Sets.

The Sound Sets and Switch Sets are entirely defined by CV lists in each sketch – all changeable via DCC Ops Mode Programming, or by editing the sketch. One can also use one Sound or Switch Set with less than 5 events – even one. A zero entry can be entered for virtually any entry, and it will be skipped or ignored.
It is possible to chain a Switch Set back to itself for permanent operation, until power reset or the MasterDecoderDisable is activated.

Examples

Here is a simple switch set to alternate blinking two LEDs at switch1 and switch8 (pin11 and pin19):

```
 {50, 0},                // Wait1 0-254 0.1 Seconds  // switch SET 1
 {51, 1},                // Switch Mode 1=0/1        // 0=NOP,1=0/1,2=RND,3=WRND,4=SND,5=SRVO,6=Dual Pin
 {52,  switch1+on},      // Switch Pin11 ON
 {53,  0},               // Wait2 0-254 0.1 Seconds
 {54, 1},                // Switch Mode 1=0/1
 {55, switch8+off},      // Switch Pin19 OFF
 {56,  8},               // Wait3 0.8 Seconds
 {57, 1},                // Switch Mode 1=0/1
 {58,  switch8+on},      // Switch Pin19 ON
 {59, 0},                // Wait4 0 Seconds / DO NOT WAIT
 {60, 1},                // Switch Mode 1=0/1
 {61, switch1+off},      // Switch Pin11 OFF
 {62,  8},               // Wait5 0-254 0.8 Seconds
 {63, 0},                // Switch Mode IGNORE
 {64, 0},                // No Operation IGNORE
```

If you change the pins used to switch1 and switch2 this switch set does the same thing:

```
 {50, 8},                // Wait1 0.8 Seconds        // switch SET 1
 {51, 6},                // Switch Mode  6=Dual Pin // 0=NOP,1=0/1,2=RND,3=WRND,4=SND,5=SRVO,6=Dual Pin
 {52,  switch1+on},      // Switch Pin11,12 ON/OFF
 {53,  8},               // Wait2 0.8 Seconds
 {54,  6},               // Switch Mode  6=Dual Pin
 {55, switch1+off},      // Switch Pin11,12  OFF/ON
 {56,  0},               // No Wait
 {57,  0},               // No Op
 {58,  0},               // No Op
 {59,  0},               // No Wait
 {60,  0},               // No Op
 {61,  0},               // No Op
 {62,  0},               // No Wait
 {63,  0},               // No Op
 {64,  0},               // No Op
```

Leaving F1 on or Input1 Pin 3 LOW will **continuously** run the alternate blinking pins

Here is another possibility to turn a switch off randomly:

```
 {50, 20},          // Wait1 2  Seconds        // switch SET 1
 {51, 2},           // Switch Mode  2=RND   // 0=NOP,1=0/1,2=RND,3=WRND,4=SND,5=SRVO,6=Dual Pin
 {52,  switch3 },   // Switch3  Pin5  RANDOMLY SET ON/OFF
 {53,  0},          // No Op
 {54,  0},          // No Op
 {55,  0},          // No Op
 {56,  0},          // No Op  …all the rest are No Op's
```

Leaving F1 on or Input1 Pin 3 LOW will continuously randomly turn the pin on and off

Each sketch has predefined Sound and Switch Sets. I always had at least 12 tracks placed on the SD memory card for testing (included in the library download zip file). Arduino Pro Mini Pin connections and operational details are described in each sketch and in the last section below -- **IDEC Decoder operational details**.

The casual modeler will note there are differing approaches to sequencing used in the IDEC library, even inconsistencies!. These represents the evolution of my thinking and use over a period of time that these were created. I include them all as the differing characteristics may be of similar use to you. If nothing else, it documents my evolutionary confusion grappling with these. I have fun with all of them. ☺

A brief functional summary of each decoder available in the library (Decoder names are indicated in each title)

Controlled Motor Drive IDEC1_1_MotSound5Led

This decoder is used to control a DC motor direction, start, stop, pause, reverse, ramp up and ramp down.

Motor speed via DCC speed for one motor

Speed Over-Ride = CV = Non-Zero Value (1-127) over-rides the DCC speed commands for both motors

Input1 for Throttle Down/Pause/Throttle Up; CV for Throttle Down Time, CV for Throttle Up Time,
CV for Pause Time, Optional sound track played

Input2 for Throttle Down/Pause/Throttle Up; CV for Throttle Down Time, CV for Throttle Up Time,
CV for Pause Time, Optional sound track played

Input1 for Throttle Down/Reverse/Throttle Up; CV for Throttle Down Time, CV for Throttle Up Time;
CV for Reverse Pause Time, Optional sound track played

Input2 for Throttle Down/Reverse/Throttle Up; CV for Throttle Down Time, CV for Throttle Up Time;
CV for Reverse Pause Time, Optional sound track played

Input for immediate Stop, Optional sound track played

Input for immediate Start, Optional sound track played

Function control of second MOTOR2 with pre-defined (CV) speed and direction

CV speeds default on (if non-zero) if decoder powers on with no DCC input

Master Disable Function Turn Function ON to disable the decoder

Functions for lights on/off

Building Lights Display IDEC2_1_Building

This decoder simulates random room lighting in a building turning on and off realistically

Functions control lighting display: random building lighting, all on/off, with rate change

Decoder powers on with no DCC input

Master Disable Function Turn Function ON to disable the decoder

Building Lights Display with One Welder IDEC2_2_Building1Wldr

This decoder simulates random room lighting in a building turning on and off realistically while simulating the activity of one welder

Functions control lighting display: random building lighting, all on/off, with rate change

One welder simulation with independent control

Decoder powers on with no DCC input

Master Disable Function Turn Function ON to disable the decoder

Building Lights Display with Two Welders IDEC2_3_Building2Wldrs

This decoder simulates random room lighting in a building turning on and off realistically while simulating the activity of two welders

Functions control lighting display: random building lighting, all on/off, with rate change

Two welder simulations with independent control

Decoder powers on with no DCC input

Master Disable Function Turn Function ON to disable the decoder

Multifunction Switching Sets IDEC2_4_FunctionSets

This is a general purpose, highly configurable sequencer/switcher that runs up to 10 Switch sets simultaneously with independent timing, each with 5 groups of CV controlled timing delays (from 1/1000 of a second to 255 minutes – 4 hours 15 minutes), with independent parameterized commands, controlling any of 8 Switch pins, by single pin or in groups, with direct, random, weighted random, alternating pairs, with sound generation, servo control, and daisy chaining switch sets to create a timed chain of a maximum of 41 controlled events

10 programmable switching sets each with up to 5 groups (delay, command mode set, output pin or argument section; switched input pins and DCC functions control simultaneous independent execution of each switching set

Decoder powers on with no DCC input

Master Disable Function Turn Function ON to disable the decoder

Multifunction Switching with Large Switch Sets IDEC2_5_LargeFunctionSetsDev

Similar to IDEC2_5_LargeFunctionSetsDev *this is a general purpose, highly configurable sequencer/switcher that runs up to 2 Switch sets simultaneously with independent timing, each with 25 groups of CV controlled timing delays (from 1/1000 of a second to 255 minutes – 4 hours 15 minutes), with independent parameterized commands, controlling any of 8 Switch pins, by single pin or in groups, with direct, random, weighted random, alternating pairs, with sound generation, servo control, and daisy chaining switch sets to create up to a timed chain of 49 controlled events*

Switched Sounds IDEC3_1_1SoundPlyr

This sound decoder will orchestrate 10 sound sets to one DFPlayer Sound module

10 programmable sound sets each with up to 5 groups (delay, volume set, track to play, with switched input pins and DCC function controls allowing for simultaneous independent play

Master Disable Function Turn Function ON to disable the decoder

Four independent LED control functions

Switched Sounds IDEC3_2_2SoundPlyrs

This sound decoder will orchestrate 10 sound sets to two DFPlayer Sound modules

10 programmable sound sets each with up to 5 groups (delay, volume set, track to play) with switched input pins and DCC function controls allowing for simultaneous independent play

Each sound set can be programmed to be played on either of 2 audio players, allowing true simultaneous sound generation

Master Disable Function Turn Function ON to disable the decoder

Four independent LED control functions

Switched Sounds IDEC3_3_4SoundPlyrs

This sound decoder will orchestrate 10 sound sets to four DFPlayer Sound modules

10 programmable sound sets each with up to 5 groups (delay, volume set, track to play) with switched input pins and DCC function controls allowing for simultaneous independent play

Each sound set can be programmed to be played on any of 4 audio players, allowing true simultaneous sound generation

Master Disable Function Turn Function ON to disable the decoder

Four independent LED control functions

IDEC4_1_ServosFastLEDsSounds

This decoder will control 10 coordinated sets of servo movements and sound tracks

10 Functions and 8 inputs servo/LEDs/sounds combinations

Master Disable Function Turn Function ON to disable the decoder

IDEC4_2_ServosLEDsSounds

This decoder will control 10 coordinated sets of servo movements and sound tracks

10 Functions and 8 inputs servo/LEDs/sounds combinations

Master Disable Function Turn Function ON to disable the decoder

IDEC4_3_ServosLEDsSounds3Plyr

This decoder will control 10 coordinated sets of servo movements and sound tracks to 3 DFPlayers sound generators

10 Functions and 8 inputs servo/LEDs/sounds combinations

Master Disable Function Turn Function ON to disable the decoder

IDEC4_4_ServosLEDsSoundsCV

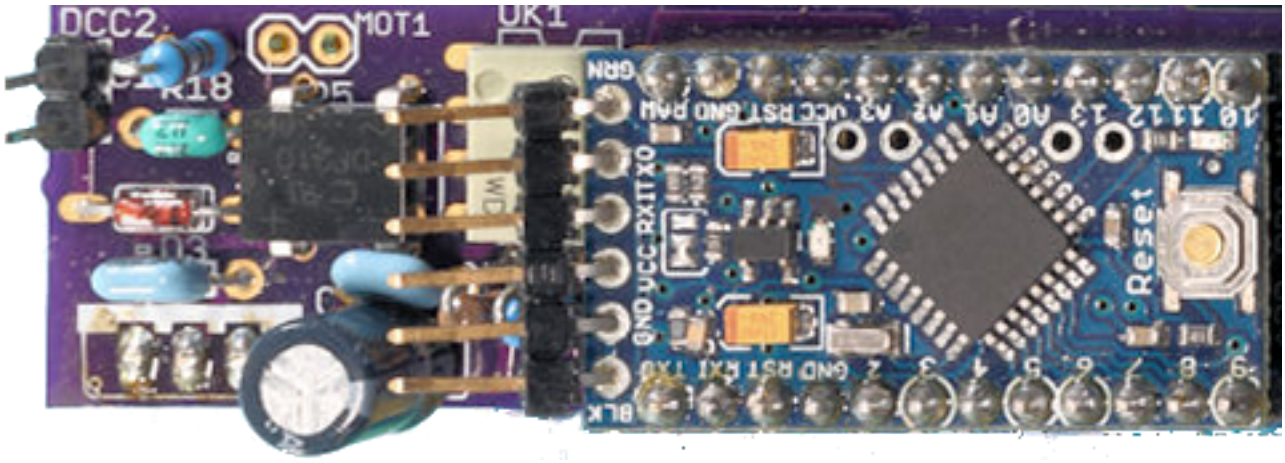
This decoder will control 10 coordinated sets of servo movements and sound tracks all CV configurable
10 Functions and 8 inputs servo/LEDs/sounds combinations
Master Disable Function Turn Function ON to disable the decoder

These additional 10 sketches can be found in the DemosAndDiagnostics folder:

IDEC1_1_MotSoundBell_Demo1_8K
IDEC1_1_MotSoundBell_Demo2_16K
IDEC2_5_LargeFunctionBellDemo4
IDEC2_5_LargeFunctionBellDemo5
IDEC2_5_LargeFunctionBellDemo6
IDEC4_4_ServosCVBell_Demo3
IDEC4_4_ServosCVBell_Demo3A
IDEC4_4_ServosCVBell_Demo3B
These are all variations of the respective IDEC library entries IDECx_y with various settings changed to suit the demo I was working on. Most changes are in the CV (DCC Control Variables) settings, but other options and parameters, like motor PWM timing in **IDEC1_1_MotSoundBell_Demo1_8K** and **IDEC1_1_MotSoundBell_Demo1_16K** are also made. These are provided as hopefully instructive examples.

IDEC9_Sound_Test
This is a debugging tool to play all 12 tracks on the SD Card in the DFPlayer connected to pin 15
IDECServoTestPin8
This is a debugging tool to run a servo connected to D8 from end to end

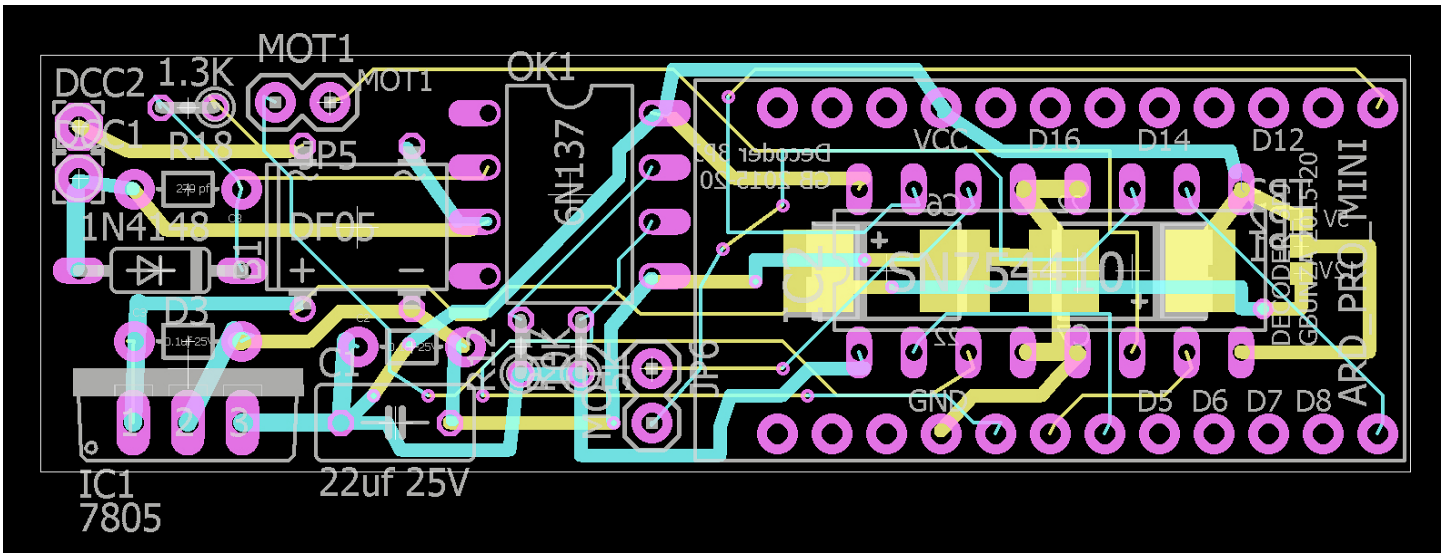
The IDEC Decoder Hardware: The SMA20 DCC Decoder Board



Many modelers have asked for printed circuit boards to make the construction a bit easier. These can use a 7805 style Voltage regulator, but a **MEZD71202A-G** DC-DC Converter 5V 2Amp from Digikey.com #1589-1465-ND $5.22 or a **PSU5a** 5V 3A Regulator in TO-220 form Factor from EZSBC.com # PSU5a $7.95 is much preferred for IDEC decoders. Further, either of these Digikey.com bridges: **DF204-G** Bridge Rectifier 400V 2Amp Digikey #641-1341-5-ND $0.59 or **DF210-G** Bridge Rectifier 1KV 2Amp Digikey #641-1343-5-ND $0.59

should be used. The original board supports the use of a dual H-Bridge which can control 2 motors, the SN754410 H-Bridge. This part is only needed for the **IDEC1_1_MotSound5Led** controlled motor drive decoder. The on-board power supply, which powers the board from the DCC bus directly, will supply 2 Amps for the decoder and attachments. This board attaches to the Arduino Pro Mini board directly, via header connectors, pins and sockets, or plain wire. The Arduino Pro Mini used here is very low cost ($1.85-$4.00), fast enough, and has enough memory to serve out purposes well. However, I have run the very same decoder sketches on Arduino Uno's, Pro Micro's, Mega2540's, and Nano's. The mother board design I provide are designed for minimal size for use directly with the Arduino Pro Mini, in form, fit, and function. The switches, sensors, LEDs and Servos are connected directly to the Pro Mini board as before. The motor connections are located on the new daughter board. Circuit diagrams are shown below.

Look to **SMA20 Low Cost 17 Channel DCC Decoders Ver 6.01 with Sound,Triggered Sound,Stepper,Dual Motor,LED and Servo Control** https://model-railroad-hobbyist.com/node/24316 for more details. Boards can be ordered from OSHPark.com with the board files available (http://model-railroad-hobbyist.com/sites/model-railroad-hobbyist.com/files/users/geoffb/decoderpcbs.zip) or from Model Railroad Control Systems (http://www.modelrailroadcontrolsystems.com/community-designs/). I have no vested interest in either – I'm just a satisfied customer. Please feel free to use whatever fabricator you like. I know of no source for fully built boards.



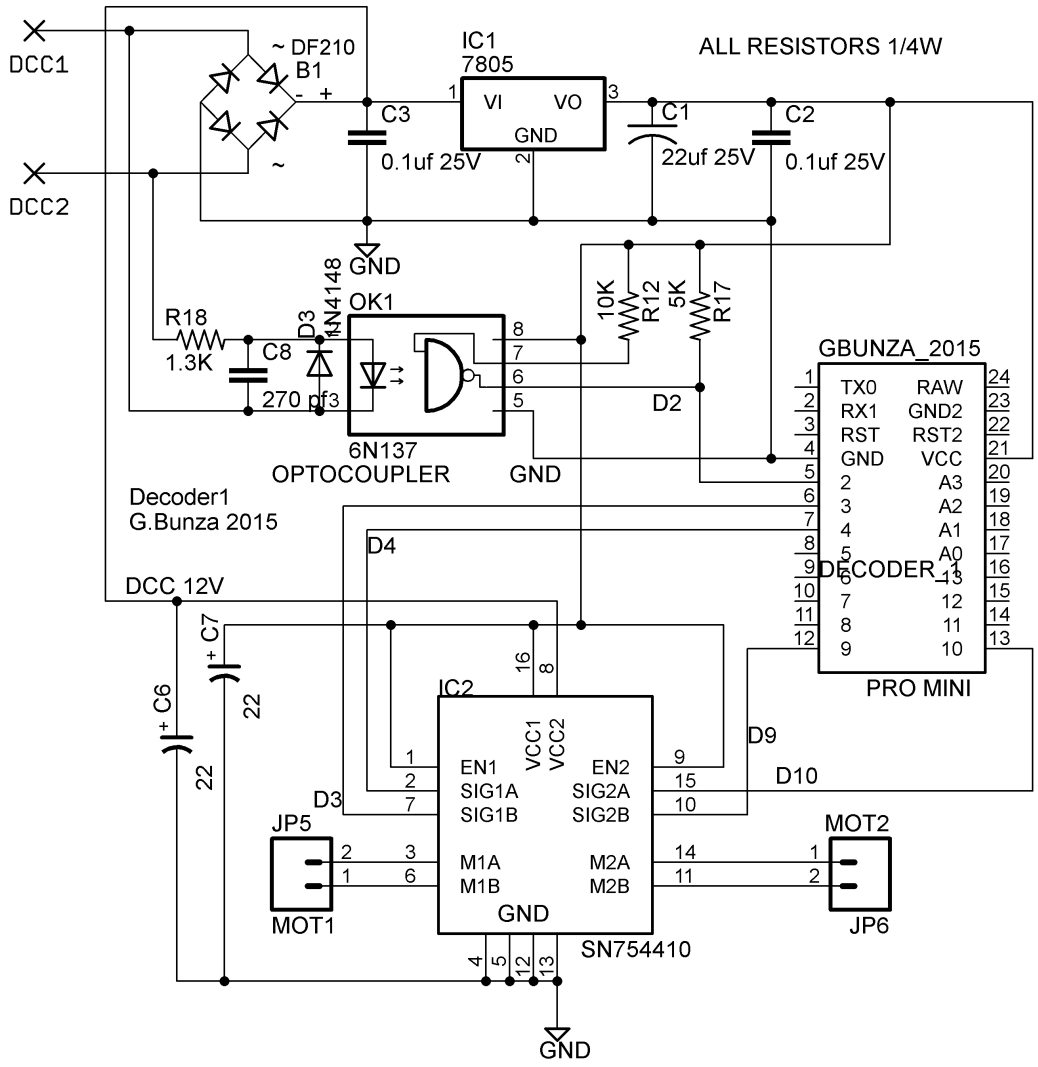
DCC_Decoder3PJ Board

Bill of Materials (BOM)

Schem Part# QTY **ALL** Digikey parts (http://www.digikey.com):

OK1	1	160-1791-ND	6N137 OPTOCOUPLER HS 8-DIP
IC1	1	497-15682-5-ND	L7805ACV-DG IC REG LDO 5V 1.5A TO220
Or better (runs cool & higher power):			
IC1	1	1589-1465-ND	MEZD71202A-G DC-DC Converter 5V 2Amp
D3	1	1N4148FSCT-ND	1N4148 DIODE GEN PURP 100V 200MA DO35
C1	1	493-5914-1-ND	CAP ALUM 220UF 25V 20% RADIAL
B1	1	641-1343-5-ND	DF210-G DIODE BRIDGE 1000V 2.0Amp 4-DIP
C6,C7	2	478-8312-1-ND	CAP TANT 22UF 25V 10% 2312 SMD

C2,C3	2	445-8421-ND	CAP CER 0.1UF 25V 10% RADIAL
C8	1	BC1018CT-ND	CAP CER 270PF 50V 5% RADIAL
R12	1	CF14JT10K0CT-ND	RES 10K OHM 1/4W 5% CARBON FILM
R17	1	CF14JT5K10CT-ND	RES 5.1K OHM 1/4W 5% CARBON FILM
R18	1	CF14JT1K30CT-ND	RES 1.3K OHM 1/4W 5% CARBON FILM
IC2	1	296-9911-5-ND	SN754410NE IC HALF-H DRVR QUAD 16-DIP
PROMINI	1	1568-1055-ND	DEV-11113 ARDUINO PRO MINI 328 5V/16MHZ
DCC,MOT1, MOT2	3	929450-01-12-I	PIN Connector Header 12 position 0.100"



DCC_Decoder3P Schematic