

APPLICATION NOTE

SET/RESET FUNCTION FOR MAGNETIC SENSORS

ABSTRACT

Honeywell's Anisotropic Magneto-Resistive (AMR) sensors are fabricated with Permalloy (NiFe) thin films that create changes in resistivity with respect to external magnetic fields. These film materials are similar to magnetic recording tapes in that strong magnetic fields can disrupt the magnetic domains of the film particles from a smooth factory orientation to arbitrary directions. Accuracy and resolution of these sensors will suffer until the film magnetic domains are "reset" to recreate a uniform direction. This application note shall detail the set and reset functions for AMR sensors including the reasons to perform this function, characteristics of set/reset components, and example circuits showing the present state of the art in set/reset pulse generation.

WHAT GETS SET AND RESET?

AMR sensors are designed in wheatstone bridge configurations, with four magneto-resistive elements that remain identical electrically when no external magnetic fields are applied. With linear-mode AMR sensors, the externally applied magnetic fields are to be limited in strength so as to not disrupt the factory set magnetic domains of the permalloy thin-film elements. Figure 1 shows three examples of magnetic orientation of the film domain structure.

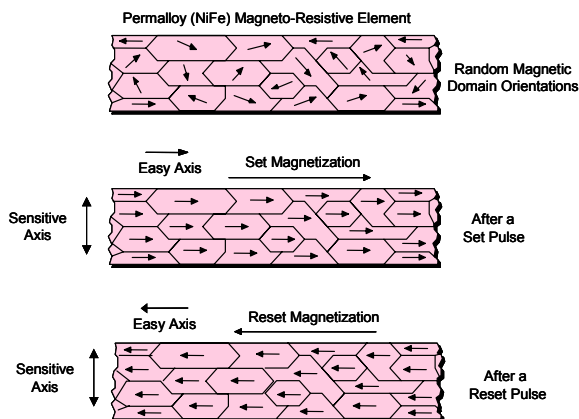


Figure 1
Magnetic Orientations

The alignment of the magnetic domains is up along the "easy" axis of the material. The "sensitive" axis is perpendicular to the easy axis direction and serves as the driving function of the magneto-resistive characteristic curve shown in Figure 2. When an external magnetic field has a vector component in the

sensitive axis, the field rotates the magnetic moment creating a change in resistance. If the external magnetic fields are in the operational field range, the magnetic moments will return to their set or reset orientations after the field is removed.

To put some numbers on the magnetic fields involved, typically a "set" or "reset" field requires about 40 or more gauss to be applied to completely orient the magnetic domains. The typical "linear" range of Honeywell's linear-mode magnetic sensors is ± 2 gauss (HMC100X series) to ± 6 gauss (HMC102X and HMC105X series). Exposure to fields under 10 gauss (HMC100X series) or fields under 20 gauss (HMC102X and HMC105X series) will not disturb the set or reset orientations.

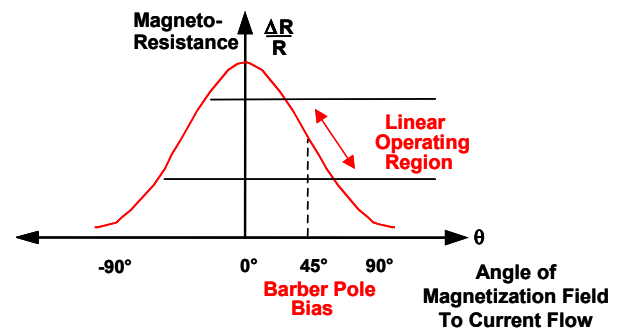


Figure 2
Characteristic Curve

WHY SET AND RESET?

The reasons to perform a set or reset on an AMR sensor are: 1) To recover from a strong external magnetic field that likely has re-magnetized the sensor, 2) to optimize the magnetic domains for most sensitive performance, and 3) to flip the domains for extraction of bridge offset under changing temperature conditions.

Strong external magnetic fields that exceed a 10 to 20 gauss "disturbing field" limit, can come from a variety of sources. The most common types of strong field sources come from permanent magnets such as speaker magnets, nearby high-current conductors such as welding cables and power feeder cables, and by magnetic coils in electronic equipment such as CRT monitors and power transformers. Magnets exhibit pole face strengths in hundreds to thousands of gauss. These high intensity magnetic field sources do not permanently damage the sensor elements, but the

magnetic domains will be realigned to the exposed fields rather than the required easy axis directions. The result of this re-magnetization of the sensor elements will be erroneous measurements and indications of “stuck” sensor outputs. Using the set and reset pulses will magnetically “restore” the sensor.

AMR sensors are also ferromagnetic devices with a crystalline structure. This same thin film structure that makes the sensor sensitive to external magnetic fields also has the downside that changing magnetic field directions and thermal energy over time will increase the self-noise of the sensor elements. This noise, while very small, does impair the accurate measurement of sub-milligauss field strengths or changes in field strength in microgauss increments. By employing frequent set and reset fields on the sensor, the alignment of the magnetic domains in each permalloy element drops the self-noise to its lowest possible level.

As the sensor element temperature changes, either due to self-heating or external environments, each element’s resistance will change in proportion to the temperature. In the wheatstone bridge configuration with the elements configured as a sensor, the bridge offset voltage and bridge sensitivity will drift with temperature. In compassing applications, the sensitivity drift of multiple sensor bridges are ignored due to the proportional method of deriving heading, but the bridge offset voltages must be updated and corrected for best accuracy as the temperature changes. One way to eliminate the bridge offset voltage is to make stable magnetic field measurements of the bridge output voltage in between each set and reset field application. Since the external field components of the bridge output voltage will flip polarity, the set and reset bridge output voltages can be subtracted and the result divided by two to calculate the bridge offset. See application note AN212 for the details on bridge offset voltage computation and correction.

SET/RESET STRAP CHARACTERISTICS

To perform the application of set and reset magnetic fields on the AMR sensor elements, Honeywell employs a patented coil co-located on the silicon die with the sensor. This coil is a planar winding or “strap” of metal wound through the active area of the elements so that an electrical current in the strap creates a corresponding magnetic field into the sensor. Figure 3 shows a photo of a typical AMR die depicting the sensor bridge elements and metalization for the set/reset and offset straps.

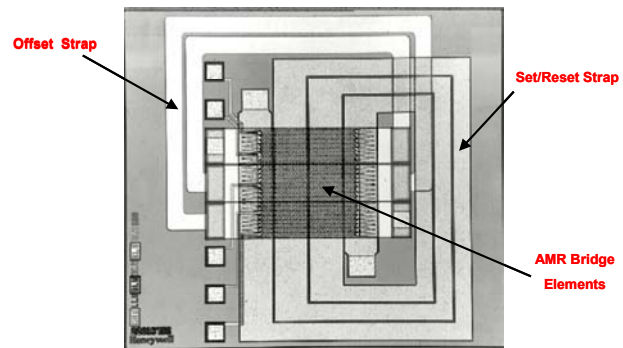


Figure 3
AMR Die

Each set/reset strap has a set of electrical characteristics that will be of unique values for each family of sensor products. The important three electrical characteristics for the set/reset strap are: 1) the strap resistance, 2) the set/reset current range, and 3) the strap resistance tempco. The following is the characteristic values for Honeywell’s three AMR sensor families:

HMC100X family: (per bridge)

Set/Reset Strap Resistance: 1.5 to 1.8 ohms

Set/Reset Strap Current: 3.0 to 5.0 amps

Set/Reset Strap Ohmic Tempco: 0.37%/°C

HMC102X family: (per bridge)

Set/Reset Strap Resistance: 5.5 to 9.0 ohms

Set/Reset Strap Current: 0.5 to 4.0 amps

Set/Reset Strap Ohmic Tempco: 0.37%/°C

HMC105X family: (per two bridges)

Set/Reset Strap Resistance: 3.0 to 5.0 ohms

Set/Reset Strap Current: 0.4 to 4.0 amps

Set/Reset Strap Ohmic Tempco: 0.37%/°C

The set/reset strap resistance specification includes the complete ohmic value for the set/reset strap metalization, the bond wires and welds, and the package lead pins from “S/R+” to “S/R-”. Typically the on-die metalization is the biggest contributor of the total ohmic value with milli-ohm contributions provided by the bond wires and pins.

The set/reset strap current is a user applied value and is generally designed so that external set/reset current pulse source circuitry will guarantee at least the minimum peak current of the pulse under worst case operational conditions. This minimum peak current value corresponds to an equivalent magnetic field imposed on the sensor bridge elements (>40 gauss) to repeatably re-align the element magnetic domains. The maximum strap current value generally is limited by the bond wire “fuzing” currents. In other words,

current exceeding the specified maximum value risks melting open the bond wires between the strap and the pins. The consequence of this scenario is that the set/reset circuit is “opened” and no longer functional.

The set/reset strap ohmic tempco value enters into the designer’s tolerance analysis for worst case circuit analysis. One design corner of the circuit will be minimum specified strap resistance further reduced by colder than ambient temperatures. This impacts the set/reset pulse source circuits so that they shall not provide excessive peak strap currents. The other design corner is the maximum specified strap resistance further increased by warmer than ambient temperatures. The impact of this tempco influenced resistance is that the designer must allot more power supply voltage to the pulse source circuit to reach the minimum required strap current. The following is an example of the calculations required:

Given: HMC1021 sensor and an industrial temperature range of -40°C to $+85^{\circ}\text{C}$.

The maximum set/reset strap resistance at ambient ($+25^{\circ}\text{C}$) is 9.0 ohms.

$+85^{\circ}\text{C}$ is 60 degrees above ambient, and multiplied by the $0.37\%/^{\circ}\text{C}$ tempco, adds 2 ohms of strap resistance; for 11.0 ohms total at $+85^{\circ}\text{C}$.

The minimum current of a HMC102X set/reset strap is 0.5 amperes peak, so 0.5 amperes times 11.0 ohms results in 5.5 volts of peak pulse voltage across the pins of a HMC1021 sensor. Extra supply voltage headroom must be added to account for voltage drops through the set/reset pulse source circuits.

Note that the set/reset strap capacitance and inductance values are not included as part of the electrical characteristics of the set/reset strap. While these values are non-zero, they are very small relative to the design of microsecond length pulses to be fed into the set/reset strap. The small ohmic value of the strap resistance, the planar orientation of the strap turns, and few turns used makes the circuit analysis of the set/reset strap non-parasitic and simulated by a simple resistor.

SET/RESET OPERATION

The above description explained that providing pulses of electrical current creates the needed magnetic fields to realign the magnetic domains of the sensor resistive elements. Also the rationale for performing these set and reset pulses has been justified. The following paragraphs shall show when and how to apply these pulsed currents, and circuits to implement them.

The above tempco math shows the importance of choosing appropriate strap voltages to create the correct strap currents and that both resistances and currents are variables to be dealt with. The direction of the strap currents also determines what is considered a “set” or a “reset” pulse. Set pulses are defined as pulsed currents that enter the positive pin of the set/reset strap. Like-wise negative pulsed currents are considered reset pulses. Figure 4 shows a simplistic schematic of a set/reset circuit.

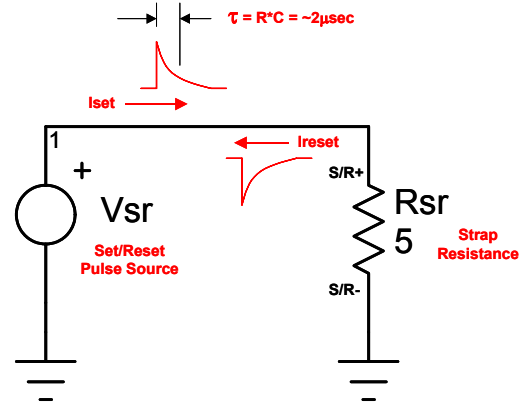


Figure 4
Set/Reset Circuit

These set and reset pulses are shown in Figure 4 as dampened exponential pulse waveforms because the most popular method of generating these relatively high current, short duration pulses is via a capacitive “charge and dump” type of circuit. Most electronics, especially in consumer battery powered devices, do not have the capability to supply these high current pulses from their existing power supply sources. Thus “Vsr” is actually a charged up capacitor that is suddenly switched across the set/reset strap. The value of this capacitor is usually a couple hundred nano-Farads (nF) to a few micro-Farads (μF) depending on the strap resistance to be driven. The decay of the exponential waveform will mostly be governed by a time constant (τ or Tau) that is the capacitance in farads multiplied by the resistance, and is measured in seconds.

Designers may also use pulse circuits that apply squared top waveforms instead of exponential waveforms. The only precaution is that the duration of pulse peaks should be kept as short as reasonable to minimize heating of the sensor bridge elements. For example, a HMC1021 with a nominal 1100 ohm bridge resistance will dissipate about 23 milliwatts with a continuous 5 volts bridge source voltage. To prevent excessive thermal drift, the power dissipated via the strap resistance should be much smaller than the bridge element thermal input. In this example, a 120 microsecond pulse width would be an additional 1%

thermal input (0.23 milliwatts) with a nominal HMC1021 strap resistance (7.7 ohms) and minimal peak pulse current (0.5 amps).

The frequency of performing the set/reset pulses is entirely application dependant, with dependencies on the power source energy capacity, and on the resolution of the magnetic field measurement. In the case of a casual sport watch with a compass feature, the set/reset action may occur as infrequently each time the user navigates to the compass display menu, to a set/reset update every several seconds. For precision magnetometer functions, such as a metal detector for security applications, the set/reset action may occur many times per second.

In a typical charge and dump circuit for set and reset applications, each capacitor charge will store a fixed amount of energy which will be dissipated or “dumped” into a load resistance composed of the set/reset strap and pulse circuit components. For example, the HMC1021 with a 5-volt supply used in the previous thermal example required at least 3.85 volts across the set/reset strap. A good design practice would be to also charge the dump capacitor further to 6.0 volts, to allocate for additional voltage losses in components and strap resistance variation. Using the energy equation of:

$$E = 0.5 \cdot C \cdot V^2 \text{ Joules}$$

And substituting 6.0 volts for V and 0.22 μ f for C, gives:

$$E = (0.5) \cdot (2.2 \cdot 10^{-7}) \cdot (6.0)^2 \text{ Joules} = 3.96 \text{ micro-Joules}$$

Or

$$E = 39.6 \text{ erg} \quad (1 \text{ Joule} = 1 \cdot 10^7 \text{ erg})$$

Note this is not power (Watts), but energy (Watt-second or Joules). This small number means that the circuit is delivering many hundreds of milli-amperes, but the duration of the pulses are so small that the energy required is very small on a per pulse basis.

To show how a designer could allocate the set/reset pulse energy, take the 3.96 micro-Joule number and work through some energy budget assumptions. For example, a typical 3.0 volt lithium watch battery has a 150mA-hour rated capacity. By multiplying the voltage by the capacity and converting hours to seconds, 1620 Watt-seconds or Joules is the result. A prudent budget would be to allocate 10% of this capacity (162 Joules) to set and reset pulses. Also, an assumption can be made that a watch battery in a watch/compass application would be replaced in a nominal 2 year increment. So 162 Joules divided by the 3.96 micro-

Joule per pulse expenditure would provide roughly for 40 million pulses. Now divide this number by two for both set and reset operation, and another division by two for the two sensors (two HMC1021 or a single HMC1022); and 10 million set/reset actions would be available for the two-year duration. This comes out to a set/reset interval of 6.3 seconds to eat up 10% of the battery’s capacity during those two years.

Another operational aspect of the set/reset function is the duration of the pulses. The previous information mentioned that the pulses should have microsecond durations to minimize die heating, and that charge and dump circuits have certain capacitances so that the exponential pulses have enough duration near the peaks for a complete set or reset magnetization. The typical minimum duration for Honeywell’s AMR sensors is 10 to 50 nano-seconds at the peak current specification. By designing the exponential pulse circuits with 1 to 2 micro-second time constants ($\tau \geq 1 \mu\text{sec}$), the pulse peak will remain at 95% or more of its peak value for more than 50 nano-seconds.

As noted during the energy calculations, the voltages applied to the set/reset straps are likely to exceed the supply voltages used on the sensor bridges. When this occurs, at least two methods can be considered to create this increased peak pulse voltage when the circuit supply voltage is less. The first method is to employ “H-bridge” type pulse drive circuits in which both ends of the set/reset strap reverse polarity. This creates twice the supply voltage across the straps with a near-perfect pulse source circuit. Figure 5 shows a basic schematic.

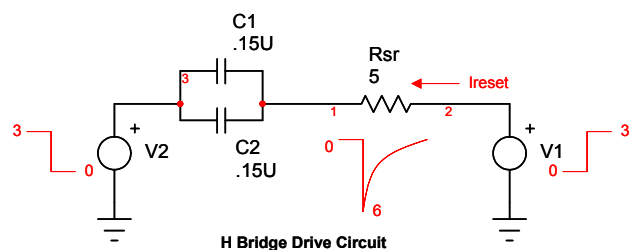


Figure 5
Simple Bridge Circuit

From the figure, sources V1 and V2 are combinations of charged capacitors and transistor switches that are timed to change voltage levels at the same moment, creating a double supply voltage swing across C1, C2, and the set/reset strap resistance (Rsr). Since the capacitors can not suddenly change their voltage, all of the voltage change is across Rsr until C1 and C2 begin to store a charge. With 3 volts as the supply, then 6 volts is theoretically available for the strap.

Another method of providing increased voltage across the set/reset strap is to employ a separate voltage boosting circuit from the normal supply. These circuit topologies run from standard switch-mode “boost” circuits to transformer based doubler circuits to capacitor charge-pump circuits. While each has differing advantages and drawbacks, all will allow simpler single-ended set/reset circuits.

SET/RESET CIRCUIT IMPLEMENTATION

A first circuit implementation is a “set – set – set” type of circuit. This design is for least critical, lowest cost compassing or magnetometer implementations of AMR sensors. A true set and reset design forces rotation of all the magnetic domains of the sensor, wiping out all the random oriented domains in one pulse in each direction. A set only design does not completely remove all the randomness in a single pulse and multiple pulse repetition is desired to achieve similar performance of set and reset circuit.

One aspect of these circuits is that completing a “set” pulse through an AMR sensor permits a positive slope of output voltage versus magnetic field intensity. When a reset pulse is that last pulse through the set/reset strap, the magnetic domains are opposite of the factory delivered orientation, and a negative slope results. Figure 6 is an example graph of these sensitivity plots after a set or a reset.

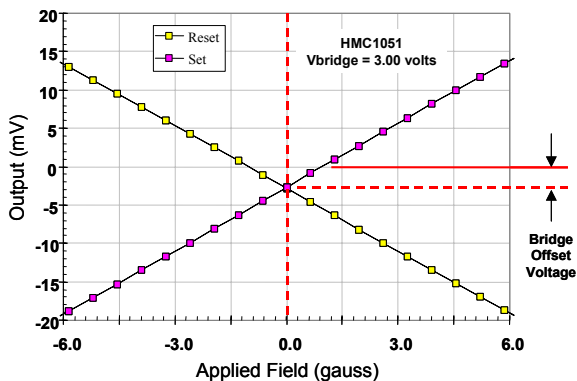


Figure 6
Sensitivity Graph

Figure 7 shows a simple set – set – set, or set only circuit implementation using a single Bipolar Junction Transistor (BJT). When driven by a microcontroller logic line, a low to high logic transition will strongly bias on (saturate) the BJT bringing its collector down to within 200 millivolts of its grounded emitter. This sudden collector swing from V_{cc} (~3.0 volts) to 0.2 volts level shifts fully charged capacitors C1 and C2 causing a voltage across the set/reset strap until the capacitors discharge down to the BJT saturation voltage. The resulting strap voltage results in a current spike that decays as a function of the total capacitance

($C1||C2$), the strap resistance loading, and the dynamic saturation resistance of the BJT.

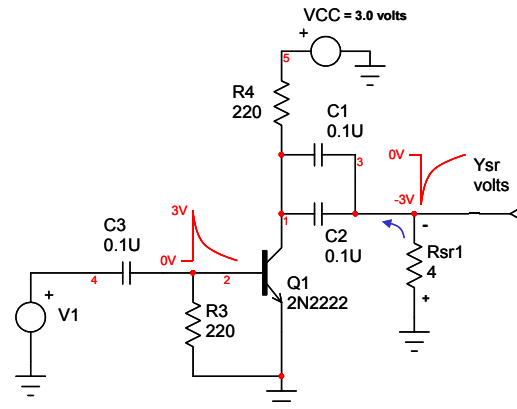


Figure 7
Set Only Circuit

In selecting components for this circuit, the BJT (Q1) is chosen for its high current gain (beta or H_{fe}), high current capability ($I_c = 800\text{mA cont.}$), small size, and low cost due to its popularity of usage. Capacitors C1 and C2 could be combined into one 0.22uF capacitor, but I chose two 0.1uF as their combined Effective Series Resistances (ESRs) are now paralleled; making the capacitor’s voltage/power losses low in comparison to the total set/reset strap resistance R_{sr1} of about 4-ohms. The strap resistance is modeled as a HMC1052 with its set/reset strap transiting through two sensor bridges.

With the combined capacitance of 0.2uF and the strap resistance of 4-ohms, the approximate time constant of the pulse decay is 0.8 microseconds and is close to the one microsecond or more guideline. In actuality, the resistive losses in the 2N2222 BJT and the C1 and C2 capacitors will accrue with the strap resistance to make the time constant greater than one microsecond.

The speed of which this circuit can repeat the set pulses is driven by the resistor R4 and capacitors C1 and C2. These set up a 44 millisecond time constant, so that five time constants (220 milliseconds) would allow the capacitors to fully recharge before dumping again into the set/reset strap. During this recharge period non-critical sensor measurements could be made, but it is recommended that the recharge be completed before making precise measurements. With 220 milliseconds between measurements, R4’s value permits only about five measurements per second. This value also limits the peak circuit current draw to only about 14mA, which is a reasonable maximum current when using coin cell lithium batteries.

The remaining components C3 and R3 have their values derived from the microcontroller interface and

the input current needs of the BJT. With a nominal beta of the 2N2222 being 200 and about a 600mA peak pulse current from the BJT collector, a 3mA peak pulse is needed into the 2N2222's base. With a nominal microcontroller logic state rise-time of 100 nanoseconds or better, the 0.1uF value of C3 looks like a near short compared to BJT base current running through it. R3's resistance is chosen in combination with C3's capacitance to turn off the BJT completely after the set pulse. A wide range of values could be used, but 220-ohms is chosen to create a 22 microsecond shutoff time constant, or five time constants later (110 μ sec) to complete base drive shutoff. This value is chosen to be very small in comparison to the C1, C2 recharge time, but large relative to the set pulse duration.

TOTEM POLE SET/RESET CIRCUIT

The next circuit implementation is the classic set/reset design in which a push-pull output stage (totem pole stage) drives one end of the set/reset strap, with the other end grounded. Figure 8 shows this circuit.

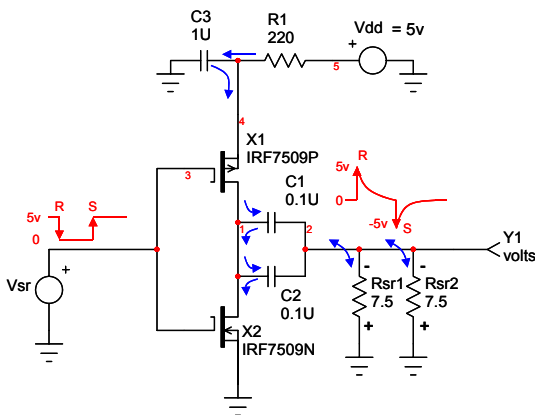


Figure 8
Set/Reset Circuit

The totem pole moniker comes from the stacked semiconductors between the positive supply voltage (Vdd) and the negative connection (Ground). In the above example circuit, the semiconductors depicted are two complementary power MOSFETs, with the P-channel device on top and the N-channel device on the bottom. The International Rectifier IRF7509 part is chosen in this circuit as it contains both P-channel and N-channel MOSFET die in a very small "micro-8" package, and has the electrical characteristics needed for this circuit. Other manufacturers can be used as well with the requirements that they can be fully turned on/off with a 5-volt logic stimulus, handle the peak set/reset strap load currents, and present an "on" resistance at those peak currents this fairly small in comparison to the connected strap load resistance.

The IRF7509 part has a couple amperes continuous drain current rating, appropriate drain-to-source voltage rating ($V_{ds} \geq 5.5$ volts), a 5-volt logic gate drive compatibility, and on-resistances of 270 milliohms or less. The set/reset strap load in figure is chosen as two HMC102X straps at nominal resistances of 7.5 ohms for a 3.75-ohm total load resistance, and each strap requiring at least 0.5 amperes of peak current.

With the input logic voltage source (V_{sr}) initially held at a high logic level state ($V_{sr} \geq 4.5$ volts), the N-channel MOSFET X2 is fully "on" and effectively grounding the series circuit of C1, C2, Rsr1, and Rsr2. As the input logic source transitions to a low logic level ($V_{sr} \leq 0.5$ volts) MOSFET X2 turns off opening up the strap resistances, while MOSFET X1 goes from its "off" state to its "on" state pulling the series R-C circuit suddenly toward the Vdd level kept by the node of X1's source and C3-R1. Again because C1 and C2 have near zero voltage initially, the sudden pull from ground to Vdd causes all the voltage to be presented to the straps Rsr1 and Rsr2 less any series resistance voltage drop on P-channel MOSFET X1. This becomes the reset spike and the current flows into the negative pins of Rsr1 and Rsr2.

As the reset pulse decays, capacitor C3 dumps part of its charge down through MOSFET X1 and into C1, C2, Rsr1, and Rsr2. Eventually capacitors C1 and C2 accumulate a full charge of near Vdd and C3 begins to recharge as well. During the stable time of all three capacitors, a sensor measurement can be taken with the knowledge that the result will be in the opposite polarity of bridge output voltage to direction of magnetic field input (sensitive axis component).

To perform the "set" pulse function, MOSFETs X1 and X2 flip on and off states, shutting off the Vdd source through X1 and suddenly connecting capacitors C1 and C2 to ground, creating a negative Vdd voltage across Rsr1 and Rsr2. The voltage application then creates the requisite current pulse that decays at a rate determined by the on resistance of X2 added to the paralleled strap resistances and capacitances of C1 and C2. This current pulse now flows into the positive pins of Rsr1 and Rsr2, defining a "set" pulse.

As the pulse current decays to zero, the sensors bridges are now at their normal factory "set" states, ready for measurements. One caution in this kind of circuit is that extreme precision magnetic field measurements should back off a few milliseconds of time after the resets and sets so that all the currents have died down below microampere levels. Even small set/reset strap currents could create measurement errors as they can couple into the bridge magneto-

resistive elements attempting to sense subtle field levels.

Component selection for the Totem Pole circuit starts with selecting C1 and C2 for the pulse time constant with total strap load resistance provided. The choice of one or two or more capacitors is driven by a number of constraints including the capacitor size, parasitics (ESR, ESL), and the temperature range for operation. Values for C3 and R1 are driven by C3 having many times the charge storage of C1/C2 and recover at a prompt time period. Typically C3 is chosen to be around 1 to 10 micro-farads with ESR being the dominant selection factor followed by size and working voltage rating. R1 is chosen after C3 to set the pulse supply recovery time and to limit peak current from the power supply source (battery, transformer). Typical values for R1 are in the range from 100 to 1000 ohms.

HIGHER VOLTAGE TOTEM POLE CIRCUITS

While the previous example uses the convenience of standard 5-volt logic supplies, many sensor designs require higher applied voltages to the set/reset straps to achieve greater currents or because the straps are series connected to assure even current distribution across all the straps pulsed. By creating series chains of straps, variances in strap resistance are less likely to fall out of the minimum or maximum range for peak pulse currents. If the straps are parallel connected, wide set/reset strap ohmic tolerances may give rise to “current hogging” and the straps will provide dissimilar magnetic fields at each sensor, potentially creating non-uniform accuracies at each sensor axis.

The circuit in Figure 8 relies on MOSFETs that could predictably be turned off and on completely using logic level inputs. At higher voltages, the P-channel device needs its gate drive voltage to approach the source voltage, which is higher than usual logic levels. To perform this level shifting from logic levels to higher pulse source voltage supply levels, a BJT level shifter sub-circuit is employed to perform this task. Figure 9 shows this higher voltage operating circuit.

From Figure 9, Rsr1, Rsr2, and Rsr3 are three strap resistances that are modeled from the HMC1001 or HMC1002 products. Three of these strap resistances are chosen since many users desire 3-axis magnetic field sensing that comes from a pairing of a HMC1001 and a HMC1002. Also this combination of three series straps is also used on the HMC2003 hybrid sensor module and in the HMR2300 Smart Digital Magnetometer.

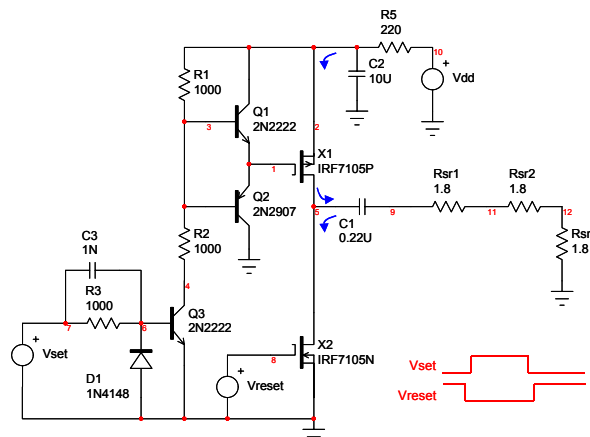


Figure 9
Higher Voltage Set/Reset Circuit

The three strap resistances are chosen at 1.8 ohms, or the worst-case high resistance points. Since they require a minimum of 3 amperes peak, the series combination requires at least 16.2 volts, so a circuit Vdd of about 18 volts would be about the right level to drive the strap load and allocate for losses in the C1 capacitor ESR and the MOSFET switches X1 and X2. C1's value is also chosen at 0.22 micro-farad so the circuit time constant is at least around 1 micro-second.

Supply reservoir capacitor C2 is chosen to many times the value of C1 and is also picked for small size, working voltage, and low ESR relative to the strap load resistance. C2 typically will be in the 1 to 10 micro-farad range and best to error on the high capacitance side since C2 now supplies additional X1 gate drive circuitry. Resistor R5 is then chosen after C2 to set the recharge time constant and to limit peak supply current.

Working backwards from the strap load resistance, MOSFETs X1 and X2 are chosen as IRF7105 due to the total packaged size (both X1 and X2 in one SOIC-8), and meeting the requirements for operating voltages, peak currents, and low on resistances. X2 is directly driven from digital logic denoted as “Vset”, and “Vreset” drives the level shifting sub-circuit to X1. Note that Vreset turns off X2 first prior to X1 being driven on by Vset, and also X1 is turned off before X2 is turned on. While one logic line could control the operation of Vset and Vreset, the additional inverter stages and pulse delay components may be too space and cost consuming compared to two logic ports in a microcontroller. See Figure 4 in Application Note 201 for the discrete Vset and Vreset pulse forming circuit.

Transistors Q1 and Q2 in Figure 9 are chosen to be generic BJTs to force MOSFET X1's gate charge quickly into on and off states. Resistors R1 and R2 are

selected as nominal 1000 ohm values that can pump or dump X1's gate charge by supplying Q1 and Q2 with enough base drive currents to flip their on and off states. Transistor Q3 is also chosen as a generic, but reasonably fast switch transistor to perform the level shift function with resistors R1 and R2. Components R3, C3 and D1 are chosen to properly drive Q3 from a logic level source, with C3 and D1 denoted as a "speed-up" network to quickly switch Q3 within a few nanoseconds of logic transitions.

H-BRIDGE SET/RESET CIRCUIT

The higher voltage drive of the Figure 9 set/reset pulse source circuit is necessary for the HMC100X series of components needing high values of minimum peak pulse currents. Many magnetic sensor circuits may not have the convenience of extra high voltage power sources and must use 5-volt supplies or even small battery voltages of 1.8 to 3.6 volts. For these applications, use of the HMC102X and HMC105X magnetic sensors is a necessity, and paralleling the set/reset strap resistances as well to keep the required minimum strap voltages low. As mentioned earlier, two totem pole stages can be driven in opposite directions across paralleled strap resistances to provide a double supply voltage drive. This dual totem-pole circuit is called an "H-bridge" circuit as the load and the totem poles schematically depict the letter H in shape. Figure 10 shows a typical H-bridge set/reset circuit.

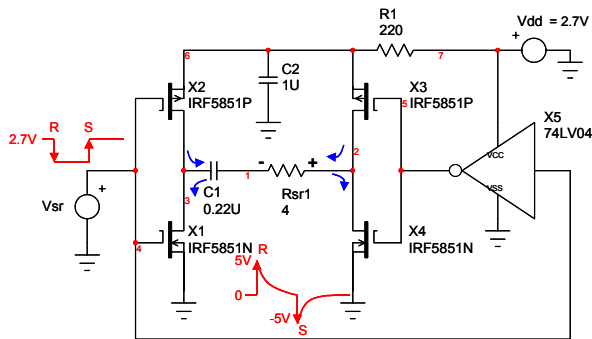


Figure 10
H-Bridge Set/Reset Circuit

From Figure 10, complementary MOSFET pairs X1 and X2, plus X3 and X4 form the totem poles of the "H". Components C1 and strap resistance Rsr1 form the center of the "H" and are driven differentially by the totem poled MOSFETs, which are in turn driven in opposite phases by the digital logic source Vsr and inverter gate X5. Inverter X5 can be substituted with another digital logic source of opposite polarity, as long as the logic outputs are sufficiently simultaneous in switching states.

In the example in Figure 10, the set/reset strap resistance is modeled as a HMC1052 set/reset strap in a nominal value of 4-ohms. Given a typical cold temperature or End-Of-Life (EOL) lithium battery condition of 2.7 volts, this circuit still manages to create pulse current peaks of around one ampere. C1 multiplied by the strap resistance nears the 1 microsecond time constant design goal, and C2 is chosen to be reasonably small physically but yet large enough electrically to supply the peak pulse currents without excessive supply droop.

MOSFETs X1 through X4 are chosen as IRF5851 complementary pairs for their 2.7V logic drive compatibility, small package size, low "on" resistance, and peak current handling ability. This circuit should appeal to circuit designers needing best set/reset circuit function for high accuracy magnetic measurements, but have a limited size and voltage source situation.

As a reminder, choose capacitors C1 and C2 for best ESR values so that the total pulse current paths have low circuit resistances compared to the strap resistance load. For example, Figure 10's reset pulse current path starts at C2, transits through X2 and then onto C1 and Rsr1. Then it completes the circuit by flowing through X4 and ground returns back to C2. With Rsr1 at 4-ohms, X2 is about 90 milli-ohms and X4 at 135 milli-ohms. By keeping the circuit losses to below 10% to 20% of the strap resistance, an 800 milli-ohm budget is established. This means that 225 milli-ohms is allocated to the MOSFETs devices and that the remainder can be consumed by the cumulative ESRs of C1 and C2.

SUMMARY

Dealing with the set/reset function in AMR sensors is one of the "Achilles Heal" parts of magnetic sensor circuit design. Although this circuit to create set/reset pulses consumes printed circuit board space, component cost, and power supply energy; the benefit is that using AMR sensors provides a passive circuit element approach to sensing external magnetic fields in a compact form. A good way of thinking about set/reset circuits is that they make a good insurance policy against end users exposing your products inadvertently to intense magnetic fields.

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